PB87-198743

Composition of Leachates from Actual Hazardous Waste Sites

IMR Corp., Washington, DC

Prepared for

Environmental Protection Agency
Cincinnati, OH

Jun 87

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-198743

EPA/600/2-87/043
June 1987

COMPOSITION OF LEACHATES FROM ACTUAL HAZARDOUS WASTE SITES

by

J. Bramlett,
C. Furman, A. Johnson,
William D. Ellis, Ph.D.,
H. Nelson, Ph.D., and
William H. Vick, Ph.D.

Science Applications International Corporation, Inc.
8400 Westpark Drive
McLean, Virginia 22102

68-03-3113, Work Assignment 39-7

Project Officer
Charles I. Mashni

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

OFFICE OF EMERGENCY AND REMEDIAL RESPONSE
OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/2-87/043	2.	3. RECIPIENT'S ACCESSION NO. PB87 198743/AS
4. TITLE AND SUBTITLE COMPOSITION OF LEACHATES FROM ACTUAL HAZARDOUS WASTE SITES		5. REPORT DATE June 1987
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. Bramlett, C. Furman, A. Johnson, N. Nelson W. Ellis, W. Vick		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS JRB Associates (SAIC) 8400 Westpark Drive McLean, Virginia 22102		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-03-3113
12. SPONSORING AGENCY NAME AND ADDRESS Hazardous Waste Engineering Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES
Project Officer: Charles I. Mashni 513/569-7857
FTS/684-7857

16. ABSTRACT

This document lists the chemical composition of leachates from 13 hazardous waste sites located through the U.S. Based on this data, laboratory formulated "leachates" were suggested to test liner compatibility.

General observations made were: 1) the leachates were approximately 99% aqueous and 1% organic by weight; 2) only 4% of the total organic carbon (TOC) was characterized; 3) of the characterized TOC, the most significant portions were organic acids and oxygenated/heteroatomic hydrocarbons. Halogenated hydrocarbons were less, but still a significant portion of the overall organics content.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 124
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

DISCLAIMER

The information in this document has been funded, wholly or in part, by the United States Environmental Protection Agency under Contract No. 68-03-3113, Work Assignment 39-7, to Science Applications International Corporation. This document has been reviewed by the Hazardous Waste Engineering Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances into the environment also have important environmental and public health complications. The Hazardous Waste Engineering Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their waste responsibly and economically.

This study was undertaken to look for patterns in the composition of leachates from several hazardous waste sites in different parts of the country and to assess the feasibility of formulating synthetic leachates representative of those from actual hazardous waste sites. The acquisition of such data is crucial for designing proper containment barriers and for developing proper treatment procedures to minimize the harmful impact on the environment. This publication provides much needed information on the complexities of the problems we are facing and better prepares us to deal with them rationally.

Thomas R. Hauser
Director
Hazardous Waste Engineering
Research Laboratory

ABSTRACT

This study was initiated with two overall objectives: 1) evaluate data on the composition and characteristics of leachates generated at hazardous waste landfills, and 2) assess the feasibility of formulating synthetic leachates to pretest liner materials and components.

Samples of leachate were collected from 13 hazardous waste landfills located throughout the United States. The samples were analyzed for various parameters and the analytical data was statistically evaluated. An attempt was made to correlate the analytical findings with climate, geography, and disposed waste.

The following observations were made: 1) the leachates were approximately 99% aqueous and 1% organic by weight; 2) only 4% of the analytical total organic carbon (TOC) was characterized; 3) of the characterized TOC (by total mean mole fraction percentage), 39.0% was organic acids, 35.8% was oxygenated/heteroatomic hydrocarbons, 11.0% was halogenated hydrocarbons, 7.2% was organic bases, 6.0% was aromatic hydrocarbons, and 0.9% was aliphatic hydrocarbons. Based on these observations, a generic formula and two specific formulas for a synthetic leachate were derived.

Recommendations were made with respect to a synthetic leachate formulation and follow-on studies. Recommendations regarding the uncharacterized organic fraction included representing it: 1) with the organics already named in the formulas; 2) based on site-specific disposed wastes; or 3) with high molecular weight liquid n-alkanes or a refined petroleum product. The study also recommended an organic portion of at least 50% to represent a localized concentration of leachate. Metals were not included since evidence from other studies indicates that these elements do not have an impact on synthetic liners. Also, correlations of leachate characteristics to factors such as climate, geographic region, and disposed waste cannot be made without comprehensive information on all factors.

Recommendations for follow-on studies included the analysis of leachate from one site to determine exactly what portion of total organics can be characterized. Analytical approaches which more comprehensively characterize leachate samples were also recommended.

CONTENTS

Page

Foreword iii
Abstract iv
Figures vi
Tables vi
Abbreviations and Symbols ix
Acknowledgments x

1. Introduction 1

2. Compilation of Information Regarding Chemical Compatibilities with Liner Materials 3
   2.1 Flexible Membrane Liners 3
   2.2 Clay Liners 6

3. Collection and Analyses of Leachate Samples 9
   3.1 Site Selection Methodology 9
   3.2 Leachate Sampling Procedures 13
   3.3 Analytical Procedures 28
   3.4 Quality Assurance/Quality Control Results 30

4. Study Findings 49
   4.1 Analytical Results 49
   4.2 Leachate Formulation 74

5. Conclusions and Recommendation 82
   5.1 Conclusions 82
   5.2 Recommendations 82

References 86

Appendices
   A. 87
   B. 93

FIGURES

Number Page

1 Average Annual Evaporation and Precipitation Rates in the United States 12

2 Geographic Distribution of Forty-three Master List Sites and Thirteen Final Sites Selected for Leachate Sampling 15

TABLES

Number Page

1 Chemical Compatibilities of Flexible Membrane Liners 5

2 Overview of Thirteen Sites Selected for Leachate Sampling and Analysis 14

3 Sample Containers and Preservation Methods 16

4 Summary of Sampling Activities 19

5 Methodologies Used for Fraction Analyses of Leachate Samples . . 31

6 QA/QC Analytical Results for Field Duplicates and Field Blanks - Metals, Total Cyanide, COD, and TOC 33

7 QA/QC Analytical Results for Field Duplicates and Field Blanks - Volatile Organics 34

8 QA/QC Analytical Results for Field Duplicates and Field Blanks - Semi-volatile Organics 35

9 QA/QC Analytical Results for Field Duplicates and Field Blanks - Non-priority Pollutants 37

10 QA/QC Analytical Results for Laboratory Blanks - Semi-volatile Organics 40

11 QA/QC Analytical Data for Laboratory Blanks - Volatile Organics 41

12 QA/QC Analytical Results for Laboratory Sample Splits - Metals . 42

13 QA/QC Analytical Results for Laboratory Sample Splits - Semi-volatiles 43

14 QA/QC Analytical Results for Laboratory Sample Splits - COD and Cyanide 39

15 QA/QC Analytical Results for Laboratory Sample Splits - TOC . . 45

16 QA/QC Analytical Results for Laboratory Surrogate Spikes - Trace Metals 46

17 QA/QC Data for Laboratory Surrogate Spikes - COD and Cyanide 48

18 QA/QC Analytical Results for Laboratory Surrogate Spikes - TOC . 48

19 Statistical Data for Organic Acids 50

20 Statistical Data for Oxygenated/Heteroatomic Hydrocarbons . . . 52

TABLES (continued)

Number Page

21 Statistical Data for Halogenated Hydrocarbons 54
22 Statistical Data for Organic Bases 55
23 Statistical Data for Aromatic Hydrocarbons 56
24 Statistical Data for Aliphatic Hydrocarbons 57
25 Statistical Data for Metals, pH, Eh, Conductivity, Temperature, Total Cyanide, and COD 58
26 Percent of Total Organic Carbon (TOC) Accounted for by Leachate Sample Analysis 60
27 Organics Data Based on Site Waste 67
28 Organics Data Based on Site Climate 69
29 Organics Data Based on Site Geography 71
30 Summary of Leachate Organic Chemical Occurrence Data 76
31 Formulation of Generic Synthetic Leachate Organic Fraction . . . 78
32 Formulations of Two Specific Synthetic Leachate Organic Fractions 79
A-1 Volatile Priority Pollutants 88
A-2 Semi-volatile Priority Pollutant 89
A-3 Metals 90
A-4 Non-priority Pollutants 91
B-1 Organic Acids--Occurrence Data 94
B-2 Oxygenated/Heteroatomic Hydrocarbons--Occurrence Data 98
B-3 Halogenated Hydrocarbons--Occurrence Data 102
B-4 Organic Bases--Occurrence Data 106
B-5 Aromatic Hydrocarbons--Occurrence Data 108
B-6 Aliphatic Hydrocarbons--Occurrence Data 110
B-7 Metals, pH, Eh, Conductivity, Total Cyanide, COD, and TOC--Occurrence Data 112

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

Butyl	- isobutylene isoprene
°C	- degrees Centigrade
CFR	- Code of Federal Regulations
CI/EI	- chemical ionization/electronic ionization
CLP	- Contract Lab Program
cmpd	- compound
cm/sec	- centimeters per second
COD	- chemical oxygen demand
CPE	- chlorinated polyethylene
CSPE	- chlorosulfonated polyethylene
CV	- coefficient of variation
Dacthal	- tetrachloroterephthalic acid
DDI	- double deionized (water)
ECD	- electron capture detector
Eh	- redox potential
EPDM	- ethylene propylene diene monomer
GC/MS	- Gas chromatography/ mass spectrometry
HDPE	- high density polyethylene
HPLC	- high performance liquid chromatography
HWDMS	- Hazardous Waste Data Management System
HWERL	- Hazardous Waste Engineering Research Laboratory (of USEPA)
Hypalon	- chlorosulfonated polyethylene (CSPE)
Hypo	- Hypalon
LDPE	- low density polyethylene
LSD	- linear scale dimension
m	- meter
MEK	- methyl ethyl ketone
MIBK	- methyl isobutyl ketone
m.f.	- mole fraction
ml	- milliliter
MPK	- methyl propyl ketone
mV	- millivolt
Neoprene	- polychoroprene
NIH	- National Institute of Health
g	- gram
PCBs	- polychlorinated biphenyls
pH	- negative log of hydrogen ion concentration
ppb	- parts per billion
ppm	- parts per million
PVC	- polyvinyl chloride
RPD	- relative percent difference
SAIC	- Science Applications International Corporation
TECL	- Trace Environmental Chemistry Laboratory (of SAIC)
TSDF/RIA	- Treatment, Storage, Disposal Facility/Regulatory Impact Analysis
TDI	- toluene diisocyanate
TOC	- total organic carbon
ug/l	- microgram per liter
umole/l	- micromole per liter
USEPA	- United States Environmental Protection Agency
UV	- ultraviolet
VOC	- volatile organic compounds

SYMBOLS

<	- less than
>	- greater than
%	- percent
±	- plus or minus

ACKNOWLEDGEMENTS

This document was prepared by Science Applications International Corporation (formerly JRB Associates) for the USEPA's Hazardous Waste Engineering Research Laboratory (HWERL), Office of Research and Development. Mr. Charlis I. Mashni, of the HWERL, served as the USEPA Project Officer.

For Science Applications International Corporation (SAIC), Dennis Pennington was the Project Manager and Dr. Edward W. Repa was the Task Manager. Another major contributor from SAIC included John W. Mentz.

The major contribution of Dr. David Taylor, an independent consultant, is gratefully acknowledged.

Analyses of the leachate samples were conducted by members of the SAIC Trace Environmental Chemistry Laboratory (TECL) under the direction of Dr. William Vick.

The valuable cooperation of staff from the USEPA Regional Offices and privately owned and operated hazardous waste management facilities is also gratefully acknowledged.

SECTION 1

INTRODUCTION

The Hazardous Waste Engineering Research Laboratory (HWERL) of the U.S. Environmental Protection Agency (USEPA) Land Pollution Control Division has been exploring the feasibility of formulating a synthetic hazardous waste leachate for use in testing containment liners currently being considered for use in landfills and other hazardous waste storage, treatment, and disposal facilities. A data base containing information on a variety of hazardous wastes and associated leachate compositions is required to assess the feasibility of such an undertaking. As such a data base does not currently exist, the USEPA issued, under Contract Number 68-03-3113, Work Assignment 39-7 entitled "Composition of Leachates from Actual Hazardous Waste Sites". The assignment or study objectives were to gather data on the composition of leachate from representative hazardous waste sites and assess the feasibility of formulating a synthetic leachate. The study data will aid in determining the type and concentration of leachate that different hazardous wastes generate and will also be available as a general reference on leachate composition.

The proposed and general approach of this study was as follows:

- Sample and analyze leachate from hazardous waste landfills located in different climatic regions in the U.S. and accepting a variety of wastes
- Develop and evaluate data on the composition of the hazardous waste leachates
- Correlate the leachate composition data with climate and the originally disposed waste to the extent possible
- Assess the feasibility of formulating synthetic leachate using the data base generated under this assignment.

The steps taken during the execution of the proposed approach consisted of the following:

- Review of existing information on liner and leachate compatibility
- Selection of thirteen hazardous waste landfill sites for leachate sampling

- Collection of leachate samples at the selected sites
- Leachate sample analysis for relevant parameters
- Evaluation of analysis results to determine leachate characteristics and comparison of results with site characteristics
- Feasibility assessment of formulating a synthetic leachate for liner compatibility testing.

This report describes the completion and results of the above steps and provides conclusions and recommendations regarding the formulation of a synthetic hazardous waste leachate. It was submitted in fulfillment of Contract No. 68-03-3111, Work Assignment 39-7, by Science Applications International Corporation, Inc., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period April 1, 1985 to September 30, 1985, and work was completed as of September 30, 1985.

SECTION 2

COMPILATION OF INFORMATION REGARDING CHEMICAL COMPATIBILITIES WITH LINER MATERIALS

Two significant problems regarding chemical compatibility testing of liners should be highlighted before summarizing available information on the subject because these problems directly influence the data base to be presented.

First, information on the compatibility of liners and multi-compound hazardous waste leachates is lacking, generally because a representative formula of such a leachate is not available. Chemical compatibility testing experiments generally have involved only a single chemical compound at a time, therefore any synergistic effects present in a multi-compound hazardous waste leachate are still relatively unknown. This study will aid in determining the formula of a synthetic, multi-compound hazardous waste leachate through the analyses and evaluation of leachate samples collected from hazardous waste sites. This multi-compound formulation could be used to more appropriately test the compatibility of liners and hazardous waste leachates by taking into account any synergistic effects.

A second significant problem is that chemical compatibility testing procedures have not been standardized, thus only generalized conclusions can be drawn from the various published reports. A possible factor contributing to this lack of test procedure standardization is the extensive timeframe - ranging from many months to years - required for each experiment. As a result of the excessive testing times and associated high costs, experimentation may simply be too limited to date to have determined an acceptable standardized testing procedure.

2.1 FLEXIBLE MEMBRANE LINERS

The chemical compatibility of organic constituents of hazardous waste leachates with flexible membrane liners has received much investigation over the past 15 years. Immersion tests represent the most commonly used laboratory procedures for reducing testing times and simulating the field environment. In these tests, a piece of flexible membrane liner is immersed in a container of the desired constituents at room temperature. The liner is exposed to chemical reactions on both sides as opposed to the single sided exposure that is actually experienced in a waste site. Quantitative results of compatibility can be obtained in roughly one year by comparing the physical properties of the liner before and after immersion (Haxo, 1979b).

The raising of test solution temperatures to 70°C can produce results in hours, however, these results compare unfavorably with those obtained at room temperature or in the field (Haxo, 1979a). On the basis of this fact, the generalizations on chemical compatibility that follow are derived solely from *in vitro* tests at room temperature and *in situ* tests.

The flexible membrane liners most commonly tested for use at hazardous waste sites are as follows:

- Isobutylene Isoprene (Butyl) Rubbers
- Chlorinated Polyethylene (CPE)
- Chlorosulfonated Polyethylene (CSPE or Hypalon)
- Elasticized Polyolefins
- Ethylene Propylene Diene Monomer (EPDM)
- Polychloroprene (Neoprene)
- High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE)
- Polyvinyl Chloride (PVC)

The information presented in Table 1 on the chemical compatibility of these liners was compiled after a review of the literature from manufacturers and independent researchers. Some of the chemical compatibility data was listed by the generalized categories found in Table 1. Other data were listed by specific compound. When the latter occurred, specific compounds representative of the leachate under study were used to draw the necessary generalized conclusions. Tests have shown that heavy metals are chemically compatible with the flexible membrane liners when tested with saturated solutions (Stewart, 1978), thus metals have been excluded from Table 1.

Isobutylene Isoprene (Butyl) Rubber

Stewart (1978) describes butyl as "a highly reliable synthetic rubber with more than twenty years of field service in the storage of potable water". Butyl shows low resistance to hydrocarbon solvents, petroleum oils, aromatic solvents, and halogenated hydrocarbons; moderate to good resistance to neutral polar liquids and bases; and high resistance to acids and oxygenated solvents.

Chlorinated Polyethylene (CPE)

CPE has excellent weathering characteristics and combines well with other ethylene polymers and vinyls to impart these characteristics (Stewart, 1978). However, as Table 1 shows, CPE has only fair to poor resistance to chemicals, oils, and other hydrocarbons.

Table 1. CHEMICAL COMPATIBILITIES OF FLEXIBLE MEMBRANE LINERS

Chemical Category	Butyl Rubber	CPE	CSPE	Elasticized Polyolefins	EPDM	Neoprene	HDPE	PVC
Organic Acids	3	2,3	2*	2*	3	3	3	3
Organic Bases	2,3	2,3	3*	No data	3*	3	3	3
Halogenated Hydrocarbons	1	1	1	1	1	2	1,2	2,3
Oxygenated Hydrocarbons	3	1	1	3	3	2	3	2,3
Aliphatic Hydrocarbons	1	2,3	2	1	1	2,3	2	2,3
Aromatic Hydrocarbons	1	1	1	1	1	1	1	2,3

*Compatibility data inferred in the literature

1 = Poor chemical compatibility (low resistance to degradation)

2 = Fair chemical compatibility

3 = Good chemical compatibility (high resistance to degradation)

Sources: Stewart, 1978; E.I. DuPont, not dated; Gundle, not dated; Schlegel, not dated.

Chlorosulfonated Polyethylene (CSPE)

CSPE, or Hypalon, is the second most widely used of polymeric flexible liner materials (Genetelli, 1976). Like CPE, CSPE has fair to poor resistance to aromatic, oxygenated, or halogenated hydrocarbons; and only fair to good resistance to oils (aliphatic hydrocarbons). CSPE shows good resistance to organic acids and bases. CSPE has been successfully used for lining holding pits and ponds in mining operations in which highly acidic fluids are encountered (Genetelli, 1976).

Elasticized Polyolefins

These polymers exhibit good resistance to oxygenated hydrocarbons; but have only fair to poor resistance to organic acids, halogenated and aromatic solvents, and aliphatic hydrocarbons.

Ethylene Propylene Diene Monomer (EPDM)

EPDM shows excellent resistance to oxygenated solvents; good resistance to organic acids and bases; and poor resistance to halogenated, aromatic, and aliphatic hydrocarbons.

Polychloroprene (Neoprene)

Although generally too costly to be used as a liner, Neoprene demonstrates good resistance to organic acids and bases, and halogenated, oxygenated, and aliphatic hydrocarbons. Only aromatic solvents exhibit a poor chemical compatibility with Neoprene.

High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE)

Like Neoprene, HDPE is typically inert to solvents. Unfortunately, even with a relatively low initial cost, HDPE is difficult to form into seams and put into place in the field. Low Density Polyethylene (LDPE) demonstrates compatibility properties similar to HDPE.

Polyvinyl Chloride (PVC)

PVC is the most widely used liner material because of a relatively low initial cost and a tolerance to a wide range of chemicals, oils, greases, and solvents (Genetelli, 1976). Of the liners listed in Table 1, PVC has the best chemical compatibility for the categories considered.

2.2 CLAY LINERS

The use of clay liners as a barrier to organic leachates depends on the ability of the clay to maintain a low permeability. In the presence of water, under normal conditions, a compacted clay is well dispersed and can maintain a permeability of 10^{-8} centimeters per second (cm/sec) or lower. Many clay-organic leachate responses, however, tend to increase permeability. For this reason, the USEPA has excluded clays as possible materials for primary liners at hazardous waste sites. Clay liners are discussed here because there is still significant interest in research regarding their use (Ground Water, 1985).

Clay permeability failure mechanisms initiated by leachate interactions typically fall into two categories: 1) development of soil structure through the pulling together (flocculation) of soil particles into aggregates with subsequent shrinkage and cracking of the clay soil structure; and 2) dissolution and piping, the dissolution of clay particles and clay binding constituents and subsequent piping (movement of the clay particles with the percolating leachates out of the clay structure)(Anderson, 1983). These two mechanisms are discussed further, and additional information on clay soil mechanics is available in references Anderson (1981) and Haxo (1980).

The failure of clays caused by the development of soil structure in a properly designed clay liner generally occurs when the cationic cloud surrounding the particles decreases in size. This change in cationic cloud size is the most common cause of clay swell-shrink and aggregate formation. When an organic liquid of lower dielectric constant (reduced ability to transmit charge) replaces water in the cationic cloud, the cloud must shrink to regain charge equilibrium, resulting in reduced spacing between clay particles (Anderson, 1983). The cationic cloud can also be reduced in size when the predominant cation is replaced with a cation of higher valence or of equal valence but smaller molecular size (Anderson, 1983). This is why sodium montmorillonite clays are less permeable than calcium or potassium montmorillonites.

An increase in the salt concentration of the leachate can also reduce the cationic cloud size by competing with the clay particle for water molecules (Haxo, 1980). Similarly, the cloud decreases with decreasing dipole movement of the cloud absorbed liquid. Although many of these mechanisms are reversible, some charges result in cationic cloud shrinkage that permanently shrink and crack the clay liner irreparably.

The second major category of clay failures, dissolution and piping, occurs: 1) when organic bases dissolve silica compounds from the clay particles or the organic constituents binding the particles; or 2) when organic acids dissolve aluminum or iron compounds. Commonly occurring organic bases were found to be too weak to produce appreciable dissolution and piping (Anderson, 1983). Research has shown, however, that even weak organic acids will dissolve clay particles. The reaction seems to be enhanced when the size and geometry of the acid anion are similar to the clay component (Haxo, 1980). One source of organic acids in the landfill environment is the anaerobic by-products of decomposed wastes; thus both the acid anion and the reactant clay component may be readily available in a clay lined landfill. In fact, the process of increasing permeability in clays by the addition of acetic, formic, or citric acid is commonly used in the oil industry to increase oil productivity and is called acidification (Anderson, 1983; Haxo, 1980). As an indication of the dissolution possible, a montmorillonite clay was found to have 33% soluble alumina (Haxo, 1980).

Piping is the mechanism that actually increases the clay's permeability. The dissolution and freed particulate matter initially decrease permeability by clogging the tiny pores in the clay structure (Anderson, 1981). Piping occurs when the soil below the liner contains 15% clay or less (Anderson, 1983) and the leachate is able to flush the freed clay components from the liner starting at the bottom and working up, gradually producing pores of increased diameter. Unlike inorganic compounds, organic solutes generally reduce surface tension of pore water (Haxo, 1980), thereby increasing flow rates which further promote piping. Some of the organic compounds that can replace water are acetonitrile, xylene, cyclopentane, alcohols, glycols, and ketones (Haxo, 1980).

An effective clay liner can be designed by considering the effects of various leachates on clay liners and accurately predicting the nature of the anticipated leachate. Conversely, leachate quality can sometimes be controlled in such a way that it will remain compatible with a given clay liner makeup. This may involve neutralization of high concentrations of acids and bases and may even require exclusion of certain leachate components entirely. The results of a USEPA-sponsored study by Lehigh University regarding the effects of various hazardous and toxic chemical solutions on three clay types are expected to be available in September 1985 (Ground Water, 1985).

SECTION 3

COLLECTION AND ANALYSES OF LEACHATE SAMPLES

This section describes the collection and analyses of leachate samples. Leachate samples were collected from a total of 13 hazardous waste landfills. Field and laboratory analyses of the leachate samples were conducted and the analytical results are presented in Section 4.

3.1 SITE SELECTION METHODOLOGY

The objective of site selection was to identify at least 10 operational and professionally managed hazardous waste landfills for the purpose of leachate sampling and analysis. The three major steps in the site selection process were:

- Compilation of a Master List of Operating Landfills. Locating landfills throughout the United States that accept either hazardous waste or a combination of municipal and hazardous wastes.
- Preliminary Screening of Candidates. Screening of located landfills based on conformance with site-specific criteria; e.g., the existence of a leachate collection system, site age, and the availability of waste type information.
- Final Site Selection. Selecting candidate landfills based on site willingness to participate, site location, waste type, and USEPA approval.

These steps are discussed in detail in the following subsections.

3.1.1 Compilation of a Master List of Operating Landfills

Site selection began with the compilation of a master list of operating landfills accepting either hazardous waste or a combination of municipal and hazardous waste. To maximize geographic and climatic coverage of landfills on this master list and provide the most complete information possible, all potential sources of information were investigated including:

- Hazardous Waste Data Management System (HWDMS), an in-house computerized data base
- Selected in-house documents and literature

- USEPA, Office of Solid Waste, Headquarters, including the Treatment, Storage, Disposal Facility/Regulatory Impact Analysis (TSDF/RIA) computerized data base and related studies
- U.S. Army Corps of Engineers, Vicksburg, Mississippi
- USEPA/HWERL, Cincinnati, Ohio
- USEPA regional offices and state regulatory agencies.

The completed master list consisted of 43 sites. Subsequent referral to a published document (McCoy, 1985), which listed all operating and commercial hazardous waste landfills in the U.S., confirmed that the master list of 43 sites accounted for the total number of operating hazardous waste landfills in the country.

3.1.2 Preliminary Screening of Candidate Sites

The second step of the site selection process was screening of candidate sites on the basis of their conformance with certain site-specific criteria. These criteria are listed below, in decreasing order of importance, and are discussed in the paragraphs that follow:

- Existence of a leachate collection system
- Accessibility of the site for leachate sampling
- Age of the site
- Accessibility of information on waste input
- Geographic and climatic location of the site.

The first of the five criteria, the existence of a leachate collection system, was mandatory. A site was eliminated from further consideration if it did not have an operating leachate collection system. Samples could be expeditiously collected only at sites with operating leachate collection systems.

The second criterion, accessibility of the site for leachate sampling, included two factors: 1) the willingness of the facility to cooperate with the contractor; and 2) the physical ease with which leachate could be sampled from the collection system. Potential sites which satisfied the criterion were ranked more positively than those sites where leachate collection appeared to be more difficult and time consuming. Many facilities could not verbally grant site access to SAIC without first receiving a written description of the project's scope and a formal request for permission to access the facility. For this reason, sites at which all other screening factors appeared favorable received letters which described the project's scope and contained a Leachate Sampling Permission Form to be returned to SAIC. The results of this effort are described in Section 3.1.3, Final Site Selection.

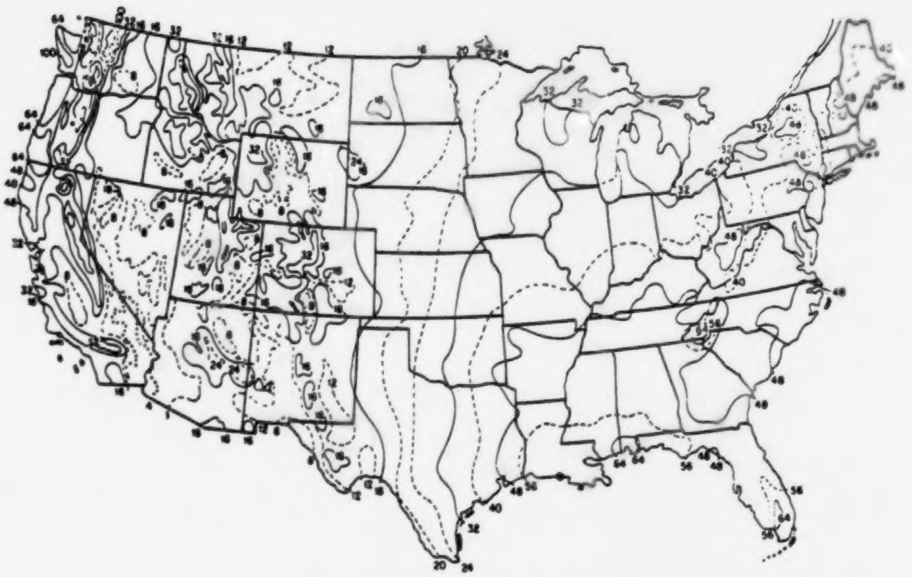
The age of a site, the third criterion, was important because age affects leachate generation rates and the quality of the leachate. A site in operation for less than five years may not generate sufficient leachate for sampling, and the generated leachate may not be representative of all the disposed wastes at the site. For these reasons, a minimum age of five years was originally designated for site screening. However, many sites or cells with leachate collection systems had operated for less than five years. Therefore, screening emphasis was instead placed on whether or not the site's leachate volume was sufficient for sampling.

The fourth significant site selection criterion was the availability of information on waste input. Adequate correlation of leachate quality to specific waste type(s) is critical in designing containment systems, thus reliable information regarding the types and quantities of disposed wastes was necessary. While this type of information was found to exist at each site, it was available at varying levels of detail and accessibility. Each site contact, however, was able to indicate whether his particular site accepted a variety of organic and inorganic wastes or only wastestreams from a specific industrial process. In some cases, complete waste input data was not made available until formal permission for project participation was granted by the site operator. Therefore, formal documentation of waste input was not available from the selected sites until after the actual sampling efforts had been completed.

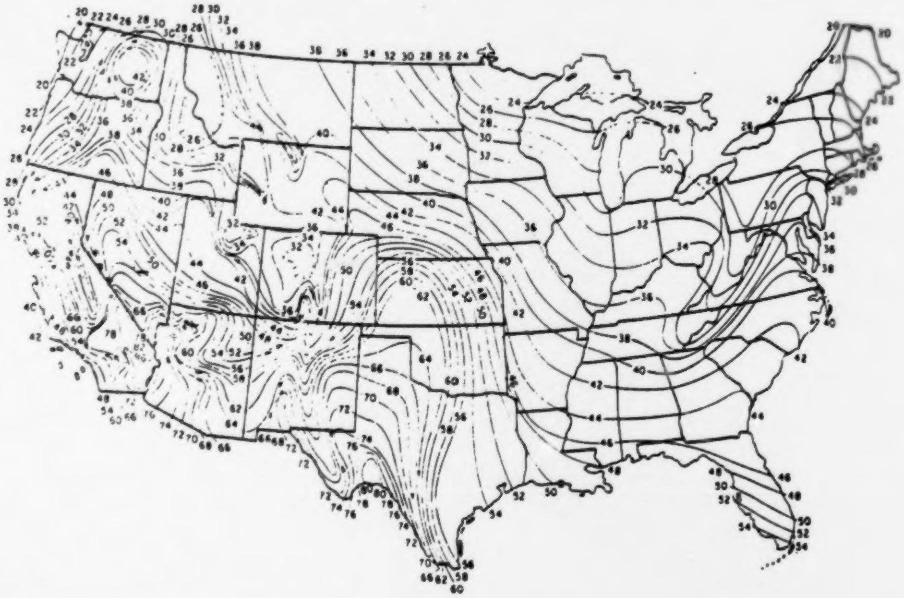
The fifth significant criterion in the site selection process was site location and associated climate. Precipitation and evaporation rates affect leachate generation rates, thus climate must be considered in the design of liner containment systems for hazardous waste facilities. Climate of a site was characterized during this process based on an area's net precipitation. Net precipitation indicates the potential for leachate generation rates at a site, and is calculated for a region by subtracting the average annual lake evaporation from the mean annual precipitation. The information shown in Figure 1 was used in the calculation of net precipitation.

An original objective of the site screening process was to select sites in areas with varying climatic conditions, thereby permitting a representative spectrum of existing site conditions. However, optimum diversity in climate was difficult to achieve while still satisfying the more important criteria discussed above. Therefore, during the final selection stage (described in Section 3.1.3), emphasis was also placed on selection of sites located in diverse geographic locations, while still maximizing climatic diversity to the extent possible.

On the basis of conformance with these screening considerations, twenty-three candidate sites were selected from the original master list for further evaluation. Site conformance with the criteria was confirmed through telephone conversations with USEPA regional offices, state regulatory agencies, and site contacts. The names and phone numbers of site contacts were, for the most part, provided by USEPA regional personnel.



Mean annual precipitation in the United States, in inches. (*U.S. Environmental Data Service.*)



Average annual evaporation (inches) from shallow lakes. (*U.S. National Weather Service.*)

FIGURE 1. Average Annual Evaporation and Precipitation Rates in the United States

3.1.3 Final Site Selection

The final evaluation of sites for leachate sampling and analysis included only those sites which had formally agreed to participate in the study. Formal permission for project inclusion was granted in a timely manner by 16 of the 23 candidate sites. Two additional sites also subsequently agreed to participate, but not in time to be included in the final site selection and site visit planning stages of the project. The 16 candidates were narrowed down to 13 by USEPA and SAIC project staff based on relative geographic locations and waste types. The selected sites demonstrated the greatest geographic and climatic diversity possible, given the criteria that had to be met, and accepted the greatest variety of wastes. Table 2 presents an overview of 13 sites selected for leachate sampling and analysis. Figure 2 illustrates the geographic distribution of both the 13 final sites and the 43 master list sites.

Several sites agreed to participate only if their own employees could conduct the sampling without the on-site participation by SAIC personnel. Three of the 13 final candidates were permitted to perform this activity using SAIC containers, enabling generation of leachate data at three additional sites without labor expenditures. The remaining ten sites were visited by SAIC personnel and sampled as described in Section 3.2, Leachate Sampling Procedures.

3.2 LEACHATE SAMPLING PROCEDURES

Prior to the actual sampling effort, each of the 10 sites was contacted to : 1) determine the most convenient time and date for sample collection; and 2) gather more detailed information regarding waste input, sampling point accessibility, and leachate collection system design. This site-specific information was necessary to predetermine the sampling technique and types of equipment that would be required in order to collect the most representative sample.

Three sampling teams, each consisting of two investigators, were assembled to conduct leachate sampling at the 10 sites which granted access to SAIC. The sampling visits to these 10 sites were scheduled over the two-week period from June 9 to June 21, 1985. The sites were divided among the three SAIC teams based on their relative geographic locations, as shown in Figure 2. Team 1 visited three Southern U.S. sites (Sites 1, 2, and 3) during the week of June 9, 1985. Team 2 visited two Western U.S. sites (Sites 5 and 6) and one Central U.S. site (Site 4) during the week of June 16, 1985. Team 3 visited three Northeastern U.S. sites (Sites 7, 8, and 9) and one Central U.S. site (Site 10) during the same week of June 16, 1985. Sampling activities common to all sites are described below in Section 3.2.1. Site characteristics and sampling activities specific to each site are described in Section 3.2.2, Site Descriptions and Site-specific Sampling Procedures.

Table 2. OVERVIEW OF THIRTEEN SITES SELECTED FOR LEACHATE SAMPLING AND ANALYSIS

Site Number	Site Age (Years)*	Waste Type Input*	Geographic Location	Net Precipitation Range (Inches)
1	3	Alkaline inorganics	Southern U.S.	-10 to +5
2	3	Variety	Southern U.S.	+10 to +15
3	5	Wide variety; inorganic and organic	Southern U.S.	+5 to +10
4	4	Wide variety; but organic concentrations are <5%	Central U.S.	-10 to +5
5	5	Wide variety; inorganic and organic	Western U.S.	<-10
6	3.5	Variety; mostly petrochemical and electroplating wastes	Western U.S.	<-10
7	6	Mostly (95%) wastewater treatment sludge	North-eastern U.S.	+5 to +10
8	7	Mostly (65%) wastewater biological treatment sludge	North-eastern U.S.	+5 to +10
9	13	Variety; inorganic and organic	North-eastern U.S.	+10 to +15
10	2	Variety; including incinerator and refinery wastes, asbestos, fly ash	Central U.S.	-10 to +5
11	10	Wide variety; organic and inorganic	North-eastern U.S.	+5 to +10
12	5	Seventy percent PCB-containing materials, 29% wastewater treatment sludge, 1% cyanides and corrosives	Central U.S.	+5 to +10
13	5	Wide variety; inorganic and organic	Southern U.S.	+10 to +15

*This information is only for the sampled portion of a site.

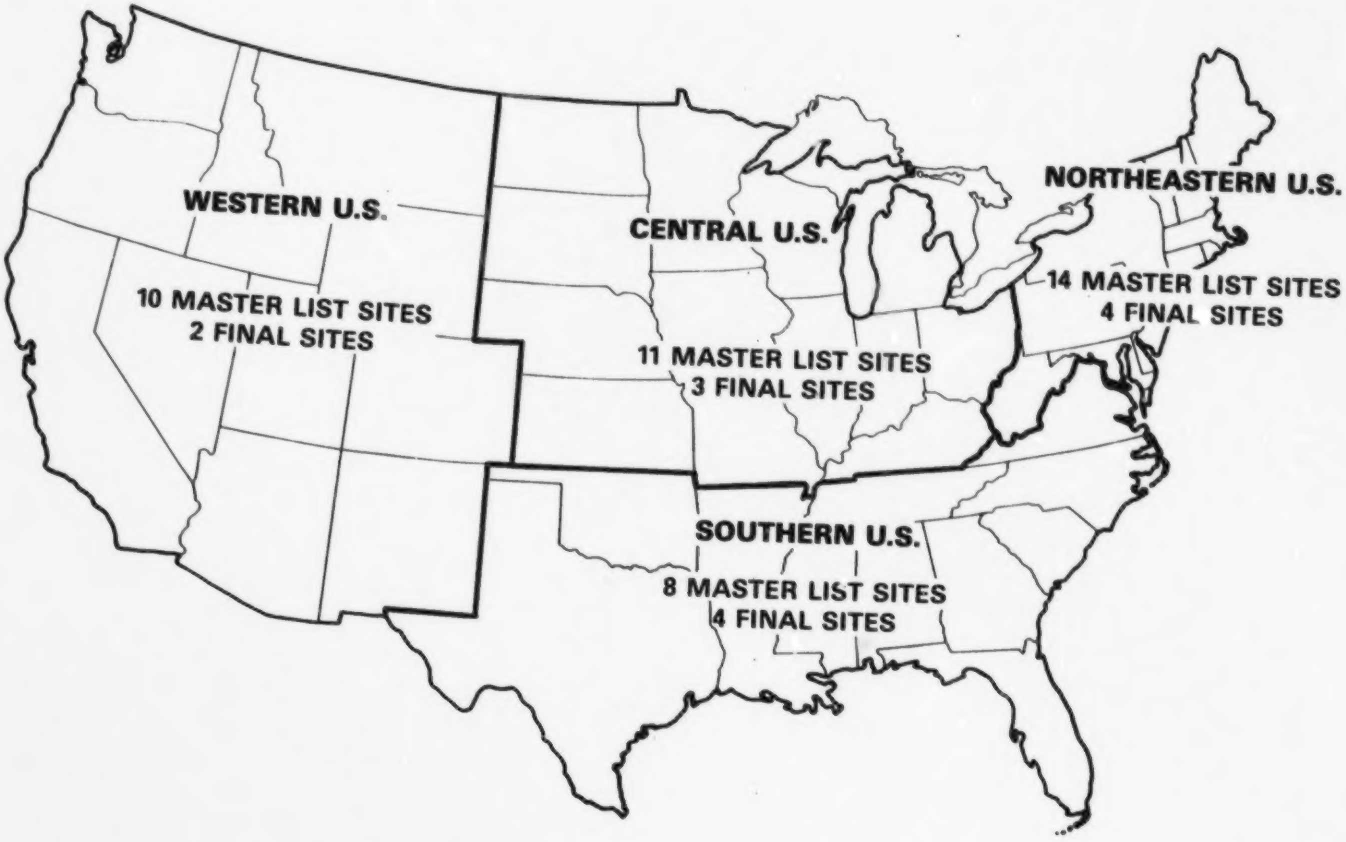

WESTERN U.S.
10 MASTER LIST SITES
2 FINAL SITES
CENTRAL U.S.
11 MASTER LIST SITES
3 FINAL SITES
NORTHEASTERN U.S.
14 MASTER LIST SITES
4 FINAL SITES
SOUTHERN U.S.
8 MASTER LIST SITES
4 FINAL SITES

FIGURE 2. Geographic Distribution of Forty-three Master List Sites and Thirteen Final Sites Selected for Leachate Sampling

3.2.1 Preparatory and Generic Sampling Procedures

The SAIC Trace Environmental Chemistry Laboratory (TECL) provided the sampling teams with prepared sample bottles containing the necessary preservatives for specific chemical group analysis. Each sample bottle set consisted of a total of six containers. Table 3 describes the sample containers and preservatives provided for each type of analysis. The TECL also provided sample bottle sets that had been pre-filled with double deionized (DDI) water. These DDI samples served as trip blanks for each traveling sampling team.

Table 3. SAMPLE CONTAINERS AND PRESERVATION METHODS

Analysis	No. of Sample Containers	Volume of Container	Type of Container	Preservative
Extractable Organics	1	2.3 liters (0.5 gallon)	glass amber bottle	none
Metals	1	1 liter	plastic bottle	nitric acid
Cyanides	1	1 liter	plastic bottle	sodium hydroxide
COD	1	250 ml	glass amber bottle	sulfuric acid
Volatile Organics	2	40 ml	vials	none

Upon receipt of the prepared sample containers from the laboratory, 23 sample bottle sets were packaged and secured in 13 portable thermal chests. Three of the 13 chests were packed with 1 sample set each and shipped to the 3 facilities that conducted their own sampling. The remaining 10 thermal chests, 1 per site, were packed with 2 prepared sample sets each. Each sampling team collected 1 baseline sample per site, and 1 duplicate sample and 1 trip blank per travel route of a team's trip. Four extra sample sets were packed in case there was bottle breakage during the sampling efforts. In total, 19 samples were collected: 13 baseline samples, 3 duplicates, and 3 blanks.

Sampling techniques and equipment for each site were selected based on sampling point accessibility and health and safety risk to the sampler. All sampling equipment was cleaned prior to the site visit using a low residue detergent wash and rinsed with DDI water. Level C personal protection equipment was used during all sampling efforts. All reusable sampling equipment was decontaminated prior to leaving each site and disposable material, e.g., coveralls and gloves, were disposed on site.

All information pertinent to field sample collection, such as field test results, point of collection, leachate appearance, etc., was recorded in a field notebook. Leachate sample collection followed USEPA sample collection protocols. As noted above, field quality assurance/quality control (QA/QC) samples were collected as performance checks for sample handling and laboratory analysis. Each team collected 1 duplicate leachate sample and 1 trip blank during their week of sampling. The duplicate leachate sample served as a check on laboratory handling and analytical procedures. At those sites where duplicates were collected, both leachate samples were collected using the same technique and equipment. The trip blanks were included to document any sample contamination resulting from sample handling and transport in the field and laboratory. Each trip blank traveled with a field leachate sample to the laboratory.

Each container was labeled and numbered after sample collection and carefully repacked in the thermal chests. The sample temperature was maintained at 4°C with bagged ice. In order to ensure site confidentiality, USEPA approval was obtained to modify standard chain-of-custody procedures for samples collected during this study. A preassigned site number was indicated on the chain-of-custody form, instead of the facility name and location. These forms were then enclosed in their respective thermal chests. The thermal chests were taped shut and securely sealed in a manner which permitted identification of any tampering during shipment to the laboratory.

The chests of samples were shipped to the laboratory, counter-to-counter, via priority freight within 24 hours of sample collection. A team member called the laboratory the day after each shipment to confirm that the samples had arrived intact. Incidents of container breakage or evidence of tampering during sample transport were not noted.

In addition to the laboratory analyses discussed earlier, four field tests were performed, when possible, on the leachate at the time of sample collection. These measurments included pH, temperature, redox potential (Eh), and conductivity. Temperature, pH, and Eh were determined using a Hach Digital pH meter, Model 19000, operated by a 9 volt transistor battery, as follows:

- Temperature was determined using the temperature probe provided with the Hach meter. The meter is able to measure temperatures from 0 to 100°C, with a resolution of 0.1°C and an accuracy of ±1°C.

- pH was determined using a Hach combination pH electrode containing a calomel reference element. The meter operates over a 0 to 14 pH range with a resolution of 0.01 pH. Values are accurate to ±0.01

pH, ±1 linear scale dimension (LSD), at Standard Temperature. The meter was calibrated daily using buffers with pH values of 4.01± 0.02 and 9.00±0.02 at 25°C.

- Eh was determined using an Orion Research platinum redox electrode, Model 97-78, in conjunction with the Hach meter. The glass envelope of the platinum redox electrode contains a silver/silver chloride reference electrode. The range of the Hach meter is -1999 millivolt (mV) to +1999 mV for Eh measurements. The meter has a resolution of 1 mV and is accurate to ±0.3% of the full scale, ±1 LSD. The filling solution used in the Orion Research electrode consisted of 4 milliliters (ml) of potassium chloride saturated with silver chloride.

- Conductivity of the leachate samples was measured with a Hach Model 16300 Portable Conductivity Meter, which uses a Hach conductivity probe with a cell constant of 2. Specific conductance is measured in five ranges: 0-2, 0-20, 0-200, 0-2000, and 0-20,000 micromhos per centimeter (micromhos/cm). Temperatures between 0°C and 100°C are compensated for automatically.

3.2.2 Site Descriptions and Site-specific Sampling Procedures

Leachate samples were collected from all 13 sites between June 9 and 21, 1985. Table 4 summarizes the sampling activities at each site. Descriptions of each site's relevant characteristics and the site-specific sampling procedures are in the following paragraphs.

Site 1 accepts a wide variety of hazardous wastes, which are segregated into cells based on whether they are acidic inorganics, alkaline inorganics, or organics. Some overlap of waste type does occur, but incompatible wastes are never disposed in the same cell. The disposed wastes include both drummed materials and bulk solids. Approximately 60 percent of all disposed wastes are bulk solids. Nothing is added to these wastes at the time of disposal and the cells are not covered until closure. A cell is closed and covered once filled to capacity, and another cell is opened to continue acceptance of that particular waste type.

Each cell at Site 1 has its own leachate collection system, in which leachate drains by gravity to a collection sump. The leachate is removed from the sump into a portable, open-topped storage tank by means of a submersible pump. The sumps are visually monitored on a daily basis and leachate is removed from any sump with more than about one meter of leachate accumulation.

Leachate from Site 1 was sampled on June 10, 1985. On that day, the site was removing leachate generated by a closed cell containing alkaline inorganics. The cell had accepted wastes from 1982 to the beginning of 1984, and was receiving final cover. The leachate was pumped from the sump into the storage tank several hours before sample collection. Leachate Samples 1 and 2 (duplicate) were collected by dipping a Teflon beaker into

Table 4. SUMMARY OF SAMPLING ACTIVITIES

Site No.	Sample Nos.	Collection Point	Sampling Method
1	1	Leachate storage tank	Collected with Teflon beaker dipped into tank, poured from beaker into sample bottles
	2	Leachate storage tank (duplicate)	
2	3	Leachate collection sump	Collected with PVC pipe used as a bailer, poured from bailer into sample bottles
3	4	Surface of leachate storage lagoon	Collected with Teflon beaker dipped into lagoon, poured from beaker into sample bottles
	5	Trip blank	
4	17	Leachate storage tank	Collected by site personnel by submerging the sample bottles in the tank
	18	Leachate storage tank (duplicate)	
5	19	Bleeder valve of leachate collection system	Collected in plastic beaker, poured from beaker into sample bottles

(Continued)

Table 4. (Continued)

Site No.	Sample Nos.	Collection Point	Sampling Method
6	20	Leachate collection sump	Collected with a Teflon point source bailer, poured from bailer into sample bottles
	21	Trip blank	
7	7	Bleeder valve of leachate collection system	Collected with a plastic jug, poured from jug into sample bottles
	11	Bleeder valve of leachate collection system (duplicate)	
8	8	Drainage pipe discharge into collection ditch	Collected directly in sample bottles
	12	Trip Blank	

(Continued)

Table 4. (Continued)

Site No.	Sample Nos.	Collection Point	Sampling Method
9	9	Leachate collection sump	Collected with a Teflon beaker lowered by twine to sump, poured from beaker into sample bottles
10	10	Galvanized tub collecting pumped leachate	Collected with a glass beaker, poured from beaker into sample bottles
11	14	Transfer line discharge into leachate storage tank	Collected with a glass beaker, poured from beaker into sample bottles
12	15	Pipe connected to collection system's pump	Collected directly in sample bottles
13	16	Pipe connected to collection system's pump	Collected directly in sample bottles

the tank and pouring the beaker's contents into the sample containers. Field tests for pH, conductivity, and temperature were conducted and recorded on site.

Leachate at Site 2 was sampled on June 11, 1985. The leachate was generated by a closed and covered trench. A variety of hazardous wastes have been disposed at the site, although specifics were not available. All of the wastes contained in the trench are bulk solids, drummed wastes were not disposed at the location.

The sampled trench at Site 2 was constructed in a chalk unit characterized by low permeability. The trench does not have a synthetic liner, compacted chalk serves as a natural liner. The trench has its own leachate collection system, wherein leachate flows by gravity to one sump. A reinforced concrete riser pipe, enclosed in a manhole 15 meters deep and approximately 1 meter in diameter, provides access to the leachate sump. The leachate generation rate is unknown, but site personnel believe it is very low because of the low permeability of the natural cover.

Sample 3 was collected at Site 2 directly from the leachate collection sump. A PVC bailer was lowered down the riser to the sump. The leachate sample was poured directly from the bailer into the sample bottles. Field tests for pH, conductivity, and temperature were also conducted on site. The leachate had a clear to slightly cloudy appearance.

Site 3 began accepting hazardous wastes in 1980. Waste disposal has occurred in numerous trenches located in two areas. One area was closed and capped in 1982, and the other area is still operating, but is currently not accepting wastes. The site has accepted a wide variety of wastes, which primarily include the following: asbestos; filter cake; residues, spent halogenated solvents, and toluene diamine from toluene diisocyanate (TDI) production; residues of cumene, isobutyl alcohols, methyl benzene, and 2-butanone; furnace dust from steel production; dimethyl ester tetrachloroterephthalic acid (Dacthal) solids; and amine solids containing lead, chromium, and TDI residues. The wastes have been disposed as bulk solids, liquids solidified with kiln dust, and drummed solids. Wastes have never been disposed as free liquids, even in drums.

Each trench at Site 3 has a dedicated leachate collection system. Leachate flows by gravity to the collection sumps and is removed by either vacuum suction or submersible pumps. Removed leachate is transported in tankers to a leachate storage surface lagoon. The on-site leachate generation rate is about 12×10^7 liters per month. The leachate is not treated or agitated in the lagoon; it is periodically removed from the lagoon for injection well disposal and to keep the leachate head below the permitted level.

Leachate at Site 3 was sampled on June 12, 1985. Sample 4 was collected from the storage lagoon's surface. A Teflon beaker was dipped into the lagoon's surface and the leachate was poured directly from the beaker into the sample containers. Conductivity and temperature were recorded. A pre-filled trip blank of DDI water (Sample 5) was shipped with Sample 4.

Site 4 has operated since 1977 and has received both hazardous and non-hazardous wastes. Until 1981, the site operated individual disposal trenches with their own leachate collection systems. These areas are now undergoing formal closure. Since 1981, the site has used a continuous trench system of waste disposal with interconnected leachate collection systems. Seventy-five to eighty percent of the wastes disposed in this system are bulk solids. Wastes have included wastewater treatment sludge from pesticide production, paint sludges, spill clean-up wastes, and heavy metal-containing wastewater treatment sludge. In addition, the site's leachate is solidified on site with cement kiln dust and returned to the disposal area. The facility does not accept liquid wastes or wastes which contain organics at a concentration greater than five percent.

Each disposal trench at Site 4 has a leachate collection trench which carries the leachate to a sump. All leachate from the sump drains into the interconnected leachate collection system's main leachate collection sump. The leachate is pumped from this main collection sump into an enclosed, aboveground storage tank and is later solidified for disposal. This system annually generates approximately 9,000 liters of leachate. Leachate from this system was sampled on June 17, 1985. As requested by facility management, Samples 17 and 18 (duplicate) were collected by facility personnel under the observation of SAIC sampling team members. Both the baseline sample and the duplicate were collected from the leachate storage tank. The leachate had been pumped into the storage tank three days earlier. The sample containers were manually submerged into the leachate through an opening located on the top of the tank. The samples were green in color. Sample temperature, conductivity, pH, and Eh were measured and recorded on site.

Site 5 accepted a wide variety of both non-hazardous and hazardous wastes between 1980 and 1982. Most of the solids and liquids were containerized in drums, although some bulk solids were accepted for disposal.

Approximately 34,500 drums were disposed at Site 5, along with other miscellaneous containers, and a little more than half of the drummed materials were solids. Containerized solids primarily included laboratory packs, asbestos, and catalyst pellets; but also filter cakes, pure caustics, cyanide-bearing solids, and some spill clean-up materials. Containerized liquids were mostly organics including various spent non-halogenated and halogenated solvents, alcohols, and aliphatic hydrocarbons. Other liquid wastes included concentrated acids and acid solutions; corrosive and caustic solutions and sludges; paint wastes and sludges, including Latex paint wastes; ink and dye wastes; and a few pesticides, mostly Lindane. Most of the bulk solids disposed at Site 5 were electroplating wastewater treatment filter cake, lime and dirt, and tetraethyl lead sludge and dirt. The wastes were covered during disposal and cover material was placed between all drums. The site is currently undergoing formal closure, whereby all wastes are being exhumed and disposed at other locations.

The leachate at Site 5 flows by gravity through drains and into the collection system sump. Submersible pumps are used to remove the leachate from the sump through riser pipe to the surface. The leachate is pumped out of the landfill at a daily rate of between 1,800 and 3,600 liters and is transported off site in tankers.

Leachate Sample 19 was collected at Site 5 on June 18, 1985. The sample was collected directly from a bleeder valve connected to the riser pipe. Disposable plastic beakers were filled from this valve and used to fill the sample containers. The leachate was buff white in color and was effervescent. The effervescence was probably caused by the combined effect of the pump pressure and the manner by which the leachate sprayed from the valve.

Site 6 has accepted hazardous wastes since late 1981. Disposed wastes have predominantly included petrochemical and electroplating wastes and sludges, and creosote contaminated solids. The wastes are disposed as bulk solids, drummed solids, and liquids solidified with fly ash.

Leachate from a cell at Site 6 was sampled on June 19, 1985. The cell had a dedicated leachate collection system above a 1.5 meter thick, compacted clay liner. Site 6 is located in an area of negative net precipitation, therefore, the leachate generation rate is very low. Leachate Sample 20 was collected from the cell's open leachate collection sump. The sump was approximately 13.6 meters deep and, at the time of sampling, held about 450 liters of leachate. The sump is purged only after heavy rainfall. A Teflon point source bailer was used to collect the leachate sample from the sump. The bailer contents were then transferred directly to the sample containers. The leachate was light brown in color. A trip blank containing DDI (Sample 21) was shipped to the TECL with Sample 20.

Site 7, which has operated for the past ten years, consists of an aboveground landfill which accepts a wide variety of drummed industrial wastes and wastewater treatment sludge. Areas within the landfill are closed once they reach capacity and new areas are opened for waste disposal.

The landfill at Site 7 is lined with a double Hypalon liner with a leak detection system between the liners. Leachate flows continuously out of the landfill's collection system to a sump. A level control in the sump automatically activates a pump for leachate removal and transfer through lines to the site's wastewater treatment plant. A faucet or bleeder valve located on the transfer line was installed specifically for leachate sample collection.

Leachate at Site 7 was sampled on June 17, 1985. The sampled leachate was generated by landfill areas which had been, on a combined basis, accepting wastes for the past six years. Over 95% of the waste disposed in these areas was wastewater treatment sludge. The sludge is sufficiently dry (45% solids) to also serve as cover for the drummed wastes. The drummed solid wastes are from the production of a wide variety of organic chemicals. The drums are set in and covered with the sludge. The areas have also accepted a small amount of solid material from spill cleanups.

Prior to sample collection at Site 7, the leachate pumping system had been kept inactivated for twenty-four hours to assure a sufficient quantity of leachate. Leachate Samples 7 and 11 (duplicate) were collected from the system's bleeder valve, as leachate was being pumped from the sump. The leachate was first collected with a plastic jug used by the facility during leachate sampling. The leachate was poured directly from the jug into the sample containers. Leachate conductivity and temperature were recorded. The leachate was clear in color.

Site 8 has operated for the past seven years. The site's landfill is an aboveground facility which has accepted both non-hazardous and hazardous wastes. Approximately two percent of waste disposed during the past two years has been municipal and industrial trash. Other wastes have included lime grit (15%), wastewater biological treatment sludge (65%) and organic chemical production waste (18%). The wastes are not formally segregated by cells and are disposed in bulk without containers. Nothing is added to any of the wastes prior to disposal. A cover, however, is applied as the wastes are placed in the landfill.

The landfill at Site 8 is lined with a double clay liner. The leachate collection system consists of three collection pipes. Leachate is drained by gravity from these pipes into a clay lined, open ditch The rate of leachate flow is not continuous, but does increase after rain and the disposal of sludge. The ditch also collects surface runoff. The leachate and runoff flow through the ditch to the site's wastewater treatment plant.

The leachate at Site 8 was sampled on June 17, 1985. Sample 8 was collected from one of the three pipes which discharge into the open ditch. The pipe did not drain any specific waste area at the landfill; but, according to site personnel, the leachate may have been generated primarily by the organic chemical production wastes. The leachate, which was cloudy in appearance, was collected directly into the sample containers from the pipe's discharge point. Leachate conductivity was recorded. A trip blank of DDI water (Sample 12) was shipped to the laboratory with Sample 8.

Site 9 is a secure landfill which has operated for the past 13 years. The landfill has formally defined cells, but the wastes are not segregated by type among the cells. The disposed wastes include both bulk solids and drummed liquids and incinerator ash. The drummed liquid wastes are mostly phenolics, toluene, other non-halogenated solvents, and oily residues. All drums are placed upright in the landfill. The bulk solids are mostly heavy metal-containing pigments. The cells are covered only at the time of their closure.

The landfill at Site 9 is lined with almost one meter of compacted clay, which is underlain by approximately 61 meters of clay and till. The leachate flows through the leachate collection system by gravity to one collection sump. The sump has a submersible pump which automatically pumps the leachate through a transfer line to the site's wastewater treatment plant. The pump is only activated when the leachate reaches a certain level in the sump. Purging after pump activation does not continue until the sump is empty, but ceases once the leachate head is below a predetermined level. The landfill's leachate generation rate is approximately 4,500 liters per day after rainfall events that allow rainfall to travel directly through the open cells to the collection system. During non-rainfall times, the rate is about 900 liters per day. The flow is generally continuous but not substantial, except during periods of precipitation.

The leachate at Site 9 was sampled on June 18, 1985. Sample 9 was collected using a Teflon beaker lowered with nylon twine into the leachate collection sump. During sampling, the pump was on for about 20 seconds. The leachate was poured directly from the Teflon beaker into the sample containers. The leachate was oily, black in color, and foamy. The leachate separated into two phases soon after being poured into the containers. An oily, black, and viscous layer formed at the top and a slightly cloudy and more liquid layer formed on the bottom. Field tests were not attempted because of this physical separation of the leachate components.

Site 10 has operated for a total of nine years and has accepted various industrial wastes including incinerator wastes, refinery wastes, asbestos, and fly ash. The wastes are either disposed in drums or as bulk solids. Acutely hazardous wastes are not accepted. Free liquids are either completely rejected, or are solidified with kiln dust and disposed as a bulk solid.

Site 10 has two cells, one of which is closed. Each cell is approximately 15 meters deep and is constructed with a double synthetic liner and dedicated leachate collection systems. The open cell has been accepting wastes for almost two years. To date, the open cell has primarily accepted bulk solids, which are spread and compacted. Drums are placed throughout the cell to provide stability. Accepted drums may not contain any free liquids. They are placed on their sides to save space and permit further checking for liquids. All wastes are covered daily.

The open cell at Site 10 actually has two leachate collection systems which are opposite each other on the east and west sides of the cell. The systems are reported to collect leachates which differ in composition, although wastes are not segregated or separated within the cell. The leachate is pumped from the collection sumps into 23 kiloliter (15,000 gallon) tankers for off-site treatment and disposal. On the average, approximately four tankers are filled every three days.

The leachate sampled at Site 10 on June 19, 1985 came from the open cell. Sample collection occurred after most of the collection sump's contents had been pumped into a tanker. The last 20 liters in the sump were pumped into a galvanized tub. A glass beaker supplied by the facility personnel was used to collect the leachate from the tub. The leachate was poured directly from the beaker into the sample containers. Leachate conductivity and pH were recorded. Leachate pH was recorded using a meter supplied by the site personnel.

Site employees at Sites 11, 12, and 13 collected leachate samples for SAIC using SAIC-prepared sample containers. Site samplers were experienced in sample collection and were familiar with USEPA sampling protocols. The samplers did not conduct field tests on the leachate; i.e., pH, Eh, conductivity, or temperature.

Site 11 has operated as a waste disposal facility for approximately 50 years. Landfills on the site accept a wide variety of hazardous wastes including, but not limited to, polychlorinated biphenyls (PCBs), organics, and flammable solids. Not more than five percent of all disposed wastes can be acutely hazardous, without first obtaining state permission.

Leachate at Site 11 was sampled on June 18, 1985 by site personnel. The leachate was generated by three closed landfills which share a leachate collection system. Each landfill is covered with a synthetic liner and the rate of surface infiltration is very low. Each landfill also has a double bottom liner system consisting of compacted clay and a polyethylene liner. Two of the landfills have bottom liner systems containing three meters of clay, and the other landfill has a liner system containing one meter of clay. Both drummed wastes and bulk solids were accepted. One landfill accepted free liquids in drums; another accepted only bulk solids; and the third also accepted drummed wastes, but was not permitted to have greater than five percent of free liquids in the drums.

Leachate at Site 11 is removed from the bottom of the landfills through the use of submersible pumps and stand pipes. The leachate flows by gravity from the stand pipes through transfer lines to a nearby 1,700 kiloliter (380,000 gallon) open leachate storage tank. The generation rate during May 1985 was 270 kiloliters. The leachate is ultimately transferred from the storage tank to an on-site wastewater treatment plant. Sample 14 was collected with a glass beaker from the transfer line at the point of discharge into the storage tank. The leachate, which was yellow, was then poured into the sample bottles.

Site 12 has operated since 1980 and accepts a wide variety of hazardous wastes. Wastes are segregated into one of three kinds of landfill cells based on waste type: 1) PCBs, wastes containing heavy metals, and wastewater treatment sludges; 2) amphoteric wastes (e.g., arsenic); or 3) all other wastes which have mostly included solvents and other organics. Each cell has its own leachate collection system. The leachate is removed with a submersible pump from the collection sump, through a PVC riser pipe, and to an aboveground holding area.

Leachate at Site 12 was sampled on June 17, 1985 from the collection system of a closed cell. The cell began accepting wastes in 1980 and was closed in 1982. Approximately 70% of all wastes disposed in the cell are PCB materials; 29% are wastewater treatment sludges (e.g., heavy metal hydroxide sludges); and 1% are cyanides, oxidizers, and other corrosive materials. Most of the waste materials were disposed in the cell as bulk solids, and not more than five percent of any drum's contents were free liquids. Seventy-five percent of the PCB material was disposed in bulk and twenty-five percent were solidified PCB liquids contained in drums. Ninety-nine percent of the wastewater treatment sludge was disposed as bulk solids and one percent was drummed. Ninety-five percent of the cyanides and other wastes were contained in drums, and five percent were disposed in bulk. Based on these figures, approximately 80% of all wastes in the cell are bulk solids and 20% are containerized. The cell is lined with a 40 ml, nylon reinforced Hypo liner and the final cover consists of 1 meter of clay, a 20 ml PVC liner, and 30 centimeters of top soil.

Leachate Sample 15 from Site 12 was collected from the aboveground branching of the cell's riser pipe. The piping was disconnected and the leachate, black in color, was collected directly into the sample bottles. The leachate came out of the piping as a steady stream and did not spray or foam.

Site 13 has operated for the past five years and has accepted several hundreds of different waste types including petrochemical wastes, paint wastes, caustics, acids, spent chlorinated solvents, laboratory packs, industrial sludges, aromatics, and plasticizers. The site landfill has individual cells, but wastes are not segregated by type into or within specific areas of cells.

The leachate at Site 13 was sampled on June 11, 1985 from a closed and covered cell. The cell had accepted a variety of hazardous wastes between 1980 and 1981. All wastes were either disposed in drums or as bulk solids. The drummed wastes were placed upright in the cell. Liquids were not accepted. A total of approximately 88,600 metric tons of waste were disposed in the cell.

The cell sampled at Site 13 has a dedicated leachate system with two collection sumps on one side. The leachate flows by gravity to these sumps. The leachate generation rate is at least 4,500 to 7,000 liters every three months. Leachate Sample 16 was obtained by using a submersible pump to bring leachate from the bottom of one of the sumps up a riser pipe to the surface. The sample was collected directly into the sample bottles. The leachate stream was steady and did not bubble or foam.

3.3 ANALYTICAL PROCEDURES

The SAIC Trace Environmental Chemistry Laboratory (TECL) in La Jolla, California, conducted the analytical tests on samples collected during the course of this study. The TECL is certified to handle and analyze hazardous waste and is a participant in USEPA's Contract Lab Program (CLP). The following is a chronology of the handling and analytical procedures utilized on each shipment of samples from the field.

Upon receipt of the leachate samples, the laboratory inspected the shipping containers (thermal chests) for tampering. All containers arrived at the laboratory intact. The samples and any subsequent splits were then assigned laboratory control numbers and were recorded in the laboratory log book. The TECL followed USEPA-approved laboratory QA/QC procedures; including those for equipment calibration, sample analysis, and internal laboratory control checks.

Laboratory sample analyses included tests for the following constituents and parameters:

- Volatile organics
- Semi-volatile organics; including acids and base/neutral extractables
- Heavy metals
- Cyanide
- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)

Analyses for volatile and semi-volatile organics included methods identified in the Federal Register; Volume 49; No. 209; October 26, 1984; 40 CFR Part 136. Metals, cyanide, COD, and TOC analyses were carried out in accordance with the guidelines identified in "Methods for Chemical Analysis of Water and Wastes," EPA 600/4-79-020, updated March 1983, as modified to CLP protocol for the USEPA. Gas chromatography followed by mass spectrometry (GC/MS) was used to identify volatile organics within three days after receipt of the samples by the laboratory, and semi-volatile organics (base/neutral and acid extractables) were analyzed within forty-two days after arrival at the laboratory.

GC/MS analyses were conducted on a Finnigan Model 4021 Automated Switchable chemical ionization or electronic ionization (CI/EI) source, GC/MS data system. The GC/MS system is equipped with the hardware and operating systems which provide all functions normally associated with a GC/MS data system; including a special library compiled from NIH/USEPA libraries, capabilities for spectral plots, listings of ions and their abundances, and plotting total ion chromatograms. In addition, the GC/MS system is capable of comparing selected spectra against a library of more than 26,000 entries by pattern recognition techniques. These various functions aided in the process of identifying compounds in the leachate samples. High performance liquid chromatography (HPLC) was performed to quantitatively evaluate water soluble components and relatively nonvolatile organics within the aqueous fraction.

A gas chromatographic method using an electron capture detector (ECD) was also used to determine PCBs and chlorinated pesticides in a sample from Site 12. The analyses were performed using a Hewlitt-Packard Model 5880A

Alpha T2 gas chromatograph with ECD; dual columns 2 meters x 4 millimeters with 3% OV-1 on 100/120 Supelcoport analytical column; temperature 207°C isothermal, 35 minute hold; injection volume 4 microliters.

Metal analyses were performed using a Perkin-Elmer Model 603 atomic absorption spectrophotometer equipped with an HGA 2200 graphite furnace, standard acetylene burner, nitrous oxide burner, deuterium arc background collector, and an AS-1 automatic sampler. The atomic absorption data was rapidly reduced via an in-house DEC 10 computer.

An Hitachi UV-visible spectrophotometer, model KONTRON UV1 KON 810, was used to quantitatively determine the concentration of cyanides drawn from the leachate samples by means of a reflux-distillation operation and absorbed in a scrubber containing sodium hydroxide solution.

The analytical procedures utilized in the laboratory to identify TOC and COD levels also followed standard EPA protocols.

The specific methodologies used for each of the fraction analysis are presented in Table 5.

3.4 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Both sampling procedures and laboratory analysis quality assurance and quality control checks were performed during this study to ensure the generation of representative and valid conclusions. These activities were conducted in accordance with USEPA recognized and approved QA/QC protocols. This section describes the procedures and evaluates the results of QA/QC sample analysis.

3.4.1 QA/QC Field Procedures and Results

During sampling, several steps were taken to ensure representativeness of samples and to check sampling and laboratory procedures. Sample representativeness was maximized by:

- Selecting a sampling point, to the extent possible, which was closest to the generation source and least likely to expose leachate to air or direct rainfall
- Taking samples directly from leachate collection systems, whenever possible, (e.g., without the use of bailers) to eliminate the potential for contamination introduced by sampling equipment
- Cleaning any required sampling equipment with a low residue detergent and a DDI water rinse prior to sampling
- Using only suitable and prepared containers supplied by the TECL to collect the samples.

Table 4 in Section 3.2.2 summarized the collection points and sampling activities by site. Sample collection points varied widely because of

Table 5. METHODOLOGIES USED FOR FRACTION ANALYSES OF LEACHATE SAMPLES

Fraction Analyzed	Analytical Method	Comments
Volatile Organics	Method 624, Federal Register, Oct. 26, 1984, 40 CFR Part 136	Samples diluted 5 or 10 times to reduce concentrations to testable levels.
Semi-volatile Organics (Base/neutral and acid extractables)	Method 625, Federal Register, Oct. 26, 1984, 40 CFR Part 136	Samples diluted 5 or 10 times to reduce concentrations to testable levels. The 24 hour continuous liquid/liquid solvent extraction system was used rather than separation funnel technique to avoid possible emulsion formation.
Heavy Metals		
Antimony	Method 204.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Arsenic	Method 206.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Beryllium	Method 210.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Cadmium	Method 213.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Chromium	Method 218.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Copper	Method 220.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Lead	Method 239.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Mercury	Method 245.1, EPA 600/4-79-020, updated 3/83	Cold Vapor, Manual
Nickel	Method 249.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Silver	Method 272.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Selenium	Method 270.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Thallium	Method 279.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Zinc	Method 289.2, EPA 600/4-79-020, updated 3/83	Atomic absorption, furnace technique
Cyanides	Method 335.2, EPA 600/4-79-020, updated 3/83	Titrimetric; Spectrophotometric
Chemical Oxygen Demand (COD)	Method 410, EPA 600/4-79-020, updated 3/83	Titrimetric, using Hach Kit
Total Organic Carbon (TOC)	Method 415.2, EPA 600/4-79-020, updated 3/83	Titrimetric Combustion or Oxidation

leachate collection system accessibility. The following lists the various sampling points:

- A leachate collection sump - Sites 2, 9, and 6
- The valve or discharge point on a pipe which carried leachate from the sump - Sites 5, 7, 8, 11, 12, and 13
- A container which collected leachate recently discharged from the pipe for the purposes of the sampling effort (Sites 1, 4, and 10)
- A storage lagoon which had held the leachate for a lengthy period (Site 3).

Leachate representativeness (i.e., sampled versus actual) was probably good for all sites except perhaps Sites 1, 3, 5, and 6 based on site observations. The sumps at Sites 1 and 6 were open to the environment and the leachate was old. The leachate at Site 3 was collected from an open storage lagoon, and the leachate at Site 5 sprayed forcibly from the bleeder valve during collection. All of these situations could have resulted in substantial loss in volatile and semi-volatile compounds.

Field QA/QC samples, i.e., field or trip blanks and duplicate samples, were collected as performance checks for sample collection, sample handling and laboratory analysis. One field blank sample and one duplicate sample were collected during each of the three sampling trips. Three field blanks, Samples 5, 12, and 21, were shipped to the laboratory with leachate Samples 3, 8, and 6, respectively. The three pairs of field duplicates, Samples 1 and 2, 7 and 11, and 17 and 18, were collected at Sites 1, 4, and 7, respectively.

The field blanks were sample containers prefilled with DDI water and supplied by the TECL prior to the site visits. Any contaminants found in the field blanks could be a result of improper sample handling, by either the samplers or the laboratory, or cross-contamination during sample shipment. Contamination may also be a result of improperly cleaned sampling or laboratory equipment or inaccurate laboratory equipment.

The field duplicate samples are two leachate samples which were taken at the same collection point and at the same time. Largely different measurements between the samples for the same parameter may be attributable to sampling conditions or methods, imprecise analysis, or improper cleaning of analytical equipment.

The results of the laboratory QA/QC analyses of these field blanks and field duplicate samples for trace metals, TOC, COD, and cyanide are presented in Table 6 and for organics in Tables 7, 8, and 9. In addition, the relative percent difference (RPD) of the duplicates is calculated to provide a means of result comparison. The RPD expresses the variance of analyses in terms of how far from the average either figure occurs. RPD is calculated by the equation: Duplicate 1 minus Duplicate 2 divided by Duplicate 1 plus Duplicate 2, wherin absolute values are used. The result is multiplied by

Table 6. QA/QC ANALYTICAL RESULTS FOR FIELD DUPLICATES AND FIELD BLANKS - METALS, TOTAL CYANIDE, COD, AND TOC

Parameter	Sample no.1	Sample no.2	RPD	Sample no.7	Sample no.11	RPD	Sample no.17	Sample no.18	RPD	Field Blanks (by sample #) 5	12	21
Metal*												
1 Silver	10.4	10.3	0.48	0.5	1.2	41	1.6	1.4	6.7	<0.30	<0.2	<0.2
2 Arsenic	468	448	2.18	596	408	18.7	<181	<181	NA	<6.9	<181	<181
3 Beryllium	<2.20	<2.20	NA	<0.1	<0.062	NA	0.3	0.4	14	<0.101	<0.1	<0.1
4 Cadmium	34.2	31.2	4.59	0.7	1.5	36.4	1.9	2.4	12	<0.3	1.0	1.0
5 Chromium	1524	1271	9.05	18.8	17.5	3.58	51.5	53.3	1.72	<0.7	<0.5	3.2
6 Copper	1137	1209	3.07	231	249	3.75	11.3	23.1	34.3	<0.6	<0.9	<0.9
7 Mercury	6910	6321	4.45	<6	<102	NA	328	401	10.0	128	18	77
8 Nickel	7590	6238	9.78	476	492	1.65	734	826	5.90	<3.40	<0.192	<0.192
9 Lead	1072	941	6.51	55.6	63.5	6.63	16.8	15.9	2.75	<0.6	5.8	6.1
10 Antimony	369	291	11.8	18.3	19.1	2.16	18.7	110	70.9	<13.0	<3.4	<3.4
11 Selenium	3178	3799	8.90	627	833	14.1	917	864	2.98	<10.8	<254	718
12 Thallium	64.9	60.6	3.43	10.7	9.7	4.90	14.3	17.8	10.9	<0.3	<3.1	15
13 Zinc	1828	1640	5.42	75.1	81.4	4.03	4.94	5.3	3.52	7.39	<1.0	6.87
Total Cyanide (mg/l)	40	40	0.00	<0.02	0.02	100	<0.02	<0.02	NA	<0.02	<0.02	<0.02
COD (mg/l)	12300	9330	13.73	3950	3940	0.13	2560	3200	11.11	<5	<5	92
TOC (mg/l)	2300	2386	1.84	1018	1077	2.82	764	672	6.41	4	4	3

* Metal data is in micrograms per liter (except for Hg, which is in nanograms per liter)

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

NA - Not Applicable

RPD- Relative Percent Difference--
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

Table 7. QA/QC ANALYTICAL RESULTS FOR FIELD DUPLICATES AND FIELD BLANKS - VOLATILE ORGANICS

Compound	Sample no.1 (ug/l)	Sample no.2 (ug/l)	RPD	Sample no.17 (ug/l)	Sample no.18 (ug/l)	RPD	Sample no.7 (ug/l)	Sample no.11 (ug/l)	RPD	Field Blanks (by sample #) 5 (ug/l)	12 (ug/l)	21 (ug/l)
1 Chloromethane	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
2 Bromomethane	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
3 Vinyl Chloride	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
4 Chloroethane	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
5 Methylene Chloride	37800	41300	4.42	2970	2700	4.76	608	601	0.579	107	100	208
6 Acetone	15700	17600	5.71	2830	2500	6.19	21600	23000	3.14	42	9 J	15
7 Carbon Disulfide	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
8 Dichloroethylene, 1,1-	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
9 Dichloroethane, 1,1-	<250	<250	NA	133	112	8.57	<250	<250	NA	<5	<5	<5
10 Trans-1,2-Dichloroethene	1520	1710	5.88	14.7 J	12 J	10.1	<250	<250	NA	<5	<5	<5
11 Chloroform	6890	7610	4.97	<250	5 J	100	1860	1850	0.270	<5	<5	<5
12 Dichloroethane, 1,2-	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
13 Butanone, 2-	14600	15300	2.34	1060	949	5.53	596	659	5.02	<10	3 J	8 J
14 Trichloroethane, 1,1,1-	<250	<250	NA	336	289	7.52	<250	<250	NA	<5	<5	<5
15 Carbon Tetrachloride	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
16 Vinyl Acetate	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
17 Bromodichloromethane	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
18 Tetrachloroethane, 1,1,2,2-	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
19 Dichloropropane, 1,2-	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
20 Trans-1,3-Dichloropropene	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
21 Trichloroethylene	5940	6820	6.90	14.4 J	12 J	9.09	80 J	75 J	3.23	<5	<5	<5
22 Dibromochloromethane	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
23 Trichloroethane, 1,1,2-	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
24 Benzene	169	185 J	4.52	9.3 J	8 J	7.51	295	246	9.06	<5	<5	<5
25 Cis-1,3-Dichloropropene	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
26 Chloroethylvinylether, 2-	<500	<500	NA	<500	<50	NA	<500	<500	NA	<10	<10	<10
27 Bromoform	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
28 Hexanone, 2-	1740	1970	6.20	1060	870	9.84	2790	2930	2.45	<10	<10	<10
29 Methyl-2-Pentanone, 4-	<500	<500	NA	12.1 J	10 J	9.50	<500	2480	100	<10	<10	<10
30 Tetrachloroethylene	875	1450	24.7	5.5 J	4 J	15.8	<250	<250	NA	<5	<5	<5
31 Toluene	7470	8870	8.57	547	423	12.8	965	946	0.994	<5	<5	<5
32 Chlorobenzene	264	<250	100	<250	<25	NA	2130	2090	0.948	<5	<5	<5
33 Ethylbenzene	70	1100	88.0	119	112	3.03	<250	<250	NA	<5	<5	<5
34 Styrene	<250	<250	NA	<250	<25	NA	<250	<250	NA	<5	<5	<5
35 Total Xylenes	416	5580	86.1	783	670	7.78	<250	<250	NA	<5	<5	<5

J - estimated value
NA - Not Applicable
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

RPD- Relative Percent Difference--
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

Table 8. QA/QC ANALYTICAL RESULTS FOR FIELD DUPLICATES AND FIELD BLANKS - SEMI-VOLATILE ORGANICS

Compound	Sample no.1 (ug/l)	Sample no.2 (ug/l)	RPD	Sample no.17 (ug/l)	Sample no.18 (ug/l)	RPD	Sample no.7 (ug/l)	Sample no.11 (ug/l)	RPD	Field Blanks [by sample #]		
										5 (ug/l)	12 (ug/l)	21 (ug/l)
1 N-Nitrosodimethylamine	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
2 Phenol	27700	22800	9.70	230	4500	90.3	7080	<600	100	<10	<10	<10
3 Aniline	47300	14700	52.6	<100	<100	NA	14600	13800	2.82	<10	<10	<10
4 Bis(2-Chloroethyl)Ether	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
5 Chlorophenol, 2-	1610	1980	10.3	<100	<100	NA	<600	<600	NA	<10	<10	<10
6 Dichlorobenzene, 1,3-	113 J	188 J	24.9	<100	<100	NA	980	1000	1.01	<10	<10	<10
7 Dichlorobenzene, 1,4-	206 J	166 J	10.8	<100	<100	NA	<600	<600	NA	<10	<10	<10
8 Benzyl Alcohol	3200	270 J	84.4	<100	<100	NA	<600	<600	NA	<10	<10	<10
9 Dichlorobenzene, 1,2,-	185 J	161 J	6.94	<100	<100	NA	<600	<600	NA	<10	<10	<10
10 Methylphenol, 2-	1720	2540	19.2	<100	<100	NA	90 J	98 J	4.26	<10	<10	<10
11 Bis(2-chloroisopropyl)Ether	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
12 Methylphenol, 4-	3580	4570	12.1	260	240	4	<600	<600	NA	<10	<10	<10
13 N-Nitroso-Di-n-Propylamine	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
14 Hexachloroethane	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
15 Nitrobenzene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
16 Isophorone	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
17 Nitrophenol,2-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
18 Dimethylphenol, 2,4-	915 J	1870	34.3	<100	<100	NA	60 J	<600	100	<10	<10	<10
19 Benzoic Acid	12100	18400	20.7	4400	2100	35.4	<3000	<3000	NA	<50	<50	<50
20 Bis(2-Chloroethoxy)Methane	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
21 Dichlorophenol, 2,4-	<1000	<500	NA	81 J	78 J	1.89	<600	<600	NA	<10	<10	<10
22 Trichlorobenzene, 1,2,4-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
23 Naphthalene	203 J	154 J	13.7	<100	53 J	100	<600	<600	NA	<10	<10	<10
24 Chloroaniline, 4-	<1000	<500	NA	<100	<100	NA	17000	14000	9.68	<10	<10	<10
25 Hexachlorobutadiene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
26 Chloro-3-Methylphenol, 4-	<1000	72 J	100	<100	<100	NA	<600	<600	NA	<10	<10	<10
27 Methylnaphthalene, 2-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
28 Hexachlorocyclopentadiene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
29 Trichlorophenol, 2,4,6-	3320	4400	14.0	<100	<100	NA	<600	<600	NA	<10	<10	<10
30 Trichlorophenol, 2,4,5-	2960 J	3920	14.0	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
31 Chloronaphthalene, 2-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
32 Nitroaniline, 2-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
33 Dimethyl Phthalate	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
34 Acenaphthylene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10

J - estimated value
NA - Not Applicable
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

RPD- Relative Percent Difference--
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

(Continued)

Table 8. (Continued)

Compound	Sample no.1 (ug/l)	Sample no.2 (ug/l)	RPD	Sample no.17 (ug/l)	Sample no.18 (ug/l)	RPD	Sample no.7 (ug/l)	Sample no.11 (ug/l)	RPD	Field Blanks (by sample #) 5 (ug/l)	12 (ug/l)	21 (ug/l)
35 Nitroaniline, 3-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
36 Acenaphthene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
37 Dinitrophenol, 2,4-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
38 Nitrophenol, 4-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
39 Dibenzofuran	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
40 Dinitrotoluene, 2,4-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
41 Dinitrotoluene, 2,6-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
42 Diethylphthalate	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
43 Chlorophenyl-phenylether, 4-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
44 Fluorene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
45 Nitroaniline, 4-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
46 Dinitro-2-Methylphenol, 4,6-	<5000	<2500	NA	<500	<500	NA	<3000	<3000	NA	<50	<50	<50
47 N-Nitrosodiphenylamine(1)	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
48 Bromophenyl-Phenylether, 4-	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
49 Hexachlorobenzene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
50 Pentachlorophenol	<5000	<2500	NA	<100	<100	NA	<3000	<3000	NA	<50	<50	<50
51 Phenanthrene	<1000	<500	NA	<500	<500	NA	<600	<600	NA	<10	<10	<10
52 Anthracene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
53 Di-n-Butylphthalate	1750	244 J	75.5	23 J	17 J	15	140 J	70 J	33.3	<10	1 J	1 J
54 Fluoranthene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
55 Benzidine	<10000	<5000	NA	<1000	<1000	NA	<6000	<600	NA	<100	<100	<100
56 Pyrene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
57 Butylbenzylphthalate	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
58 Dichlorobenzidine, 3,3-	<2000	<1000	NA	<200	<200	NA	<1200	<1200	NA	<20	<20	<20
59 Benzo(a)Anthracene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
60 Bis(2-Ethylhexyl)Phthalate	826 J	2140	44.3	<100	<100	NA	<600	<600	NA	<10	<10	<10
61 Chrysene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
62 Di-n-Octyl Phthalate	<1000	62 J	100	<100	<100	NA	<600	<600	NA	<10	<10	<10
63 Benzo(b)Fluoranthene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
64 Benzo(k)Fluoranthene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
65 Benzo(a)Pyrene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
66 Indeno(1,2,3-cd)Pyrene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
67 Dibenz(a,h)Anthracene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10
68 Benzo(g,h,i)Perylene	<1000	<500	NA	<100	<100	NA	<600	<600	NA	<10	<10	<10

J - estimated value

NA - Not Applicable

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

RPD- Relative Percent Difference--
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

Table 9. QA/QC ANALYTICAL RESULTS FOR FIELD DUPLICATES AND FIELD BLANKS - NON-PRIORITY POLLUTANTS

Compound	Sample no.1 (ug/l)	Sample no.2 (ug/l)	RPD	Sample no.17 (ug/l)	Sample no.18 (ug/l)	RPD	Sample no.7 (ug/l)	Sample no.11 (ug/l)	RPD	Field Blanks (by sample #)		
										5 (ug/l)	12 (ug/l)	21 (ug/l)
1 Alkanol	--	2040	100	--	--	NA	--	--	NA	--	--	--
2 Benzene, 1,2,3-Trimethyl-	2340	2130	4.70	--	--	NA	--	--	NA	--	--	--
3 Benzene, 2-Ethyl-1,4-Dimethyl-	1930	--	100	--	--	NA	--	--	NA	--	--	--
4 Benzene-1,2-dicarboxylic Acid	--	--	NA	--	--	NA	--	--	NA	--	--	--
5 Benzenesulfonamide, 2-Methyl-	--	--	NA	164	146	5.81	--	--	NA	--	--	--
6 Benzenesulfonamide, 4-Methyl	--	--	NA	216	180	9.09	--	--	NA	--	--	--
7 Benzoic Acid, 4-(1,1-Dimethylethyl)-	--	1350	100	--	--	NA	--	--	NA	--	--	--
8 Butanoic Acid, 2-Methyl-	--	1020	100	--	--	NA	--	--	NA	--	--	--
9 Cyclobutene, 2-Propenylidene-	--	--	NA	300	--	100	--	--	NA	--	--	--
10 Cyclohexanone	4620	3240	17.6	--	--	NA	--	--	NA	--	--	--
11 Cyclopentanol, 2-Methyl	21000	14600	18.0	--	--	NA	--	--	NA	--	--	--
12 Ethane, 1,1'-Oxybis[2 Methoxy-	1080	--	100	--	--	NA	--	--	NA	--	--	--
13 Ethanol, 1-(2-Butoxyethoxy)-	--	2460	100	--	--	NA	--	--	NA	--	--	--
14 Ethanol, 2,2'- Thiobis-	2860	5000	27.2	--	--	NA	--	--	NA	--	--	--
15 Ethanol, 2-(2-Butoxyethoxy)-	1880	--	100	--	--	NA	--	--	NA	--	--	--
16 Ethanol, 2-Butoxy	--	3130	100	--	--	NA	--	--	NA	--	--	--
17 Ethanol,2-(2-Ethoxyethoxy)-	--	2420	100	--	--	NA	--	--	NA	--	--	--
18 Heptadecane	--	1150	100	--	--	NA	--	--	NA	--	--	--
19 Hexanoic Acid, 2-Ethyl-	--	2300	100	--	--	NA	--	--	NA	--	--	--
20 Hexanol, 2-Ethyl-, 1-	--	1180	100	614	--	100	--	--	NA	--	--	--
21 Methane, Sulfonylbis-	--	3130	100	--	--	NA	--	--	NA	--	--	--
22 Naphtho[1,8-CD]Pyran-1,3-Dione, 1H,3H-	--	--	NA	--	--	NA	--	--	NA	--	--	--
23 Phenol, 2,5-Dimethyl-	--	635	100	--	--	NA	--	--	NA	--	--	--
24 Phenol, 2-Chloro-	1000	1180	8.26	--	--	NA	--	--	NA	--	--	--
25 Phenol, 3-(1,1-Dimethylethyl)-	1050	--	100	--	--	NA	--	--	NA	--	--	--
26 Phenol, 4-(Methylthio)-	--	--	NA	782	757	1.62	--	--	NA	--	--	--
27 Phenylacetic Acid	--	3310	100	--	--	NA	--	--	NA	--	--	--
28 Phenylpropanoic Acid	--	--	NA	--	--	NA	--	--	NA	--	--	--
29 Propanoic Acid, 2-Methyl-	10800	--	100	--	--	NA	--	7320	100	--	--	--
30 Hexanone, 5-Methyl-, 2- *	--	--	NA	--	--	NA	--	--	NA	--	14.6	14.2

* 5-Methyl-2-Hexanone was detected only in the field blanks

-- - Not Detected

NA - Not Applicable

RPD- Relative Percent Difference--
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

100 to get a percentage. A high RPD value indicates poor replicability of results. However, if concentration levels are low, a high RPD value is not critical.

The metal analyses results for field duplicates presented in Table 6 show very good replicability with the exception of antimony values in Samples 17 and 18. One sample reportedly contained almost six times more antimony than the other. The reason for this is unknown, however, the discrepancy is not serious because the concentrations were low.

The field blank QA/QC analytical results presented in Table 6 show contamination of mercury in all three blanks, lead and cadmium in both Samples 12 and 21, and selenium, thallium, and chromium in Sample 21. Mercury was detected in all of the samples which traveled with the field blanks, hence cross-contamination cannot be ruled out. Lead, zinc, cadmium, chromium, and thallium were also detected in the leachate samples traveling with the blanks containing these elements. However, both lead and selenium were detected in the companion leachate sample from Site 6 at a lower concentration than detected in the respective field blank. The reason for this could be the analytical procedures or inherent contamination in the DDI water.

Field duplicate analyses for organic compounds had very good replicability as shown by Tables 7, 8, and 9. The only instances of RPD values greater than 75% were found between Samples 1 and 2. Nevertheless, the concentrations reported were also small. Discrepancies in these analyses might be attributable to the fact that the original samples had very high concentrations of numerous chemical species, which makes interpretation of data subject to some ambiguity.

Results of field blank analyses for organics indicate small contamination levels of acetone, 2-butanone, and di-n-butylphthalate. Also, at larger concentrations, methylene chloride was detected in all three field blanks. More interestingly, 5-methyl-2-hexanone was detected only in field blanks and not in any of the leachate samples. The latter suggests either improper analytical procedures, improperly cleaned sample containers, or inherent contamination in the DDI water and rules out cross-contamination. Nevertheless, the field blank analytical results for organics did not show any serious problems and demonstrated good overall QA/QC.

3.4.1 QA/QC Laboratory Procedures and Results

Internal steps taken by the TECL to assess QA/QC included:

- Analyzing laboratory blank samples in addition to field blanks to assess laboratory sample handling and equipment cleaning
- Splitting selected samples into two or more separate samples to verify analytical precision
- Analyzing samples of known concentrations (surrogate spikes) to calibrate and check the accuracy of instruments.

Tables 10 and 11 present the results of laboratory blank QA/QC analyses for organics. The results are excellent from the standpoint of QA/QC, and only show detected contamination in three instances. Di-n-butylphthalate was estimated as present in Lab Blank 1, but at below the detection limit. Acetone and 2-butanone were detected at small concentrations in Lab Blank 5.

Table 12 presents the results of laboratory sample split QA/QC analyses for metals. The laboratory chose to split leachate Samples 7 and 15 for the analyses. The results were very good with respect to QA/QC.

Table 13 presents the results of laboratory sample split QA/QC analyses for semi-volatiles. The laboratory split leachate Sample 17 for the analyses and, again, the results show very good replicability.

Table 14 below presents the results of laboratory sample split QA/QC analyses for COD and cyanide. Leachate samples 17 and 8 and internal samples were analyzed. The QA/QC analytical results for these laboratory splits were very good.

Table 14. QA/QC ANALYTICAL RESULTS FOR LABORATORY SAMPLE SPLITS - COD AND CYANIDE

Parameter and Sample I.D.	Replicate 1 (mg/l)	Replicate 2 (mg/l)	RPD
COD			
8506 0455*	<5	<5	NA
8506 0954*	42	43	1.1
Sample 8**	13,700	13,600	.4
Cyanide			
8506 0280*	<0.02	<0.02	NA
8506 0699*	<0.02	<0.02	NA
8506 0093*	15.9	10.2	21.8
Sample 17**	<0.02	<0.20	NA

* EPA QC Sample I.D.

** Leachate study baseline sample

RPD - Relative Percent Difference

NA - Not applicable

Table 10. QA/QC ANAYLTICAL RESULTS FOR LABORATORY BLANKS - SEMI-VOLATILE ORGANICS

Compound	Lab Blank 1 (ug/l)	Lab Blank 2 (ug/l)	Compound	Lab Blank 1 (ug/l)	Lab Blank 2 (ug/l)
1 N-Nitrosodimethylamine	<10	<10	35 Nitroaniline, 3-	<50	<50
2 Phenol	<10	<10	36 Acenaphthene	<10	<10
3 Aniline	<10	<10	37 Dinitrophenol, 2,4-	<50	<50
4 Bis(2-Chloroethyl)Ether	<10	<10	38 Nitrophenol, 4-	<50	<50
5 Chlorophenol, 2-	<10	<10	39 Dibenzofuran	<10	<10
6 Dichlorobenzene, 1,3-	<10	<10	40 Dinitrotoluene, 2,4-	<10	<10
7 Dichlorobenzene, 1,4-	<10	<10	41 Dinitrotoluene, 2,6-	<10	<10
8 Benzyl Alcohol	<10	<10	42 Diethylphthalate	<10	<10
9 Dichlorobenzene, 1,2,-	<10	<10	43 Chlorophenyl-phenylether, 4-	<10	<10
10 Methylphenol, 2-	<10	<10	44 Fluorene	<10	<10
11 Bis(2-chloroisopropyl)Ether	<10	<10	45 Nitroaniline, 4-	<50	<50
12 Methylphenol, 4-	<10	<10	46 Dinitro-2-Methylpherol, 4,6-	<50	<50
13 N-Nitroso-Di-n-Propylamine	<10	<10	47 N-Nitrosodiphenylamine *	<10	<10
14 Hexachloroethane	<10	<10	48 Bromophenyl-Phenylether, 4-	<10	<10
15 Nitrobenzene	<10	<10	49 Hexachlorobenzene	<10	<10
16 Isophorone	<10	<10	50 Pentachlorophenol	<50	<50
17 Nitrophenol,2-	<10	<10	51 Phenanthrene	<10	<10
18 Dimethylphenol, 2,4-	<10	<10	52 Anthracene	<10	<10
19 Benzoic Acid	<50	<50	53 Di-n-Butylphthalate	1 J	<10
20 Bis(2-Chloroethoxy)Methane	<10	<10	54 Fluoranthene	<10	<10
21 Dichlorophenol, 2,4-	<10	<10	55 Benzidine	<100	<100
22 Trichlorobenzene, 1,2,4-	<10	<10	56 Pyrene	<10	<10
23 Naphthalene	<10	<10	57 Butylbenzylphthalate	<10	<20
24 Chloroaniline, 4-	<10	<10	58 Dichlorobenzidine, 3,3-	<20	<10
25 Hexachlorobutadiene	<10	<10	59 Benzo(a)Anthracene	<10	<10
26 Chloro-3-Methylphenol, 4-	<10	<10	60 Bis(2-Ethylhexyl)Phthalate	<10	<10
27 Methylnaphthalene, 2-	<10	<10	61 Chrysene	<10	<10
28 Hexachlorocyclopentadiene	<10	<10	62 Di-n-Octyl Phthalate	<10	<10
29 Trichlorophenol, 2,4,6-	<10	<10	63 Benzo(b)Fluoranthene	<10	<10
30 Trichlorophenol, 2,4,5-	<50	<50	64 Benzo(k)Fluoranthene	<10	<10
31 Chloronaphthalene, 2-	<10	<10	65 Benzo(a)Pyrene	<10	<10
32 Nitroaniline, 2-	<50	<50	66 Indeno(1,2,3-cd)Pyrene	<10	<10
33 Dimethyl Phthalate	<10	<10	67 Dibenz(a,h)Anthracene	<10	<10
34 Acenaphthylene	<10	<10	68 Benzo(g,h,i)Perylene	<10	<10

J - estimated value

* Cannot be separated from diphenylamine

< - The compound was analyzed for but not detected. The number is the minimum attainable detection limit for the sample.

Table 11. QA/QC ANALYTICAL RESULTS FOR LABORATORY BLANKS - VOLATILE ORGANICS

Compound	Lab Blank 3 (ug/l)	Lab Blank 4 (ug/l)	Lab Blank 5 (ug/l)
1 Chloromethane	<10	<10	<10
2 Bromomethane	<10	<10	<10
3 Vinyl Chloride	<10	<10	<10
4 Chloroethane	<10	<10	<10
5 Methylene Chloride	<5	<5	<5
6 Acetone	<10	<10	29
7 Carbon Disulfide	<5	<5	<5
8 Dichloroethylene, 1,1-	<5	<5	<5
9 Dichloroethane, 1,1-	<5	<5	<5
10 Trans-1,2-Dichloroethene	<5	<5	<5
11 Chloroform	<5	<5	<5
12 Dichloroethane, 1,2-	<5	<5	<5
13 Butanone, 2-	<10	<10	15
14 Trichloroethane, 1,1,1-	<5	<5	<5
15 Carbon Tetrachloride	<5	<5	<5
16 Vinyl Acetate	<10	<10	<10
17 Bromodichloromethane	<5	<5	<5
18 Tetrachloroethane, 1,1,2,2-	<5	<5	<5
19 Dichloropropene, 1,2-	<5	<5	<5
20 Trans-1,3-Dichloropropene	<5	<5	<5
21 Trichloroethylene	<5	<5	<5
22 Dibromochloromethane	<5	<5	<5
23 Trichloroethane, 1,1,2-	<5	<5	<5
24 Benzene	<5	<5	<5
25 cis-1,3-Dichloropropene	<5	<5	<5
26 Chloroethylvinylether, 2-	<10	<10	<10
27 Bromoform	<5	<5	<5
28 Hexanone, 2-	<10	<10	<10
29 Methyl-2-Pentanone, 4-	<10	<10	<10
30 Tetrachloroethylene	<5	<5	<5
31 Toluene	<5	<5	<5
32 Chlorobenzene	<5	<5	<5
33 Ethylbenzene	<5	<5	<5
34 Styrene	<5	<5	<5
35 Total Xylenes	<5	<5	<5

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

Table 12. QA/QC ANALYTICAL RESULTS FOR LABORATORY SAMPLE SPLITS - METALS

	Sample 7					Sample 15				
Metal*	7a	7b	7c	Mean	% RSD	15a	15b	15c	Mean	% RSD
Silver	0.519	0.471	0.454	0.481	7	2.70	2.45	2.79	2.65	7
Arsenic	551.0	723.0	515.0	596	19	8993	8109	8565	8556	5
Beryllium	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA
Cadmium	0.494	0.812	0.710	0.672	24	2.64	2.43	2.57	2.55	4
Chromium	19.5	19.5	17.4	18.8	6	0.250	0.186	0.201	0.212	16
Copper	231	219	243	231	5	5726	3624	4007	4452	25
Mercury	ND	ND	ND	NA	NA	561	688	569	606	12
Nickel	486	450	492	476	5	1159	1103	1159	1140	3
Lead	59.7	53	54	56	6	0.367	0.322	0.308	0.332	9
Antimony	15.8	20.6	18.5	18.3	13	133	146	132	137	6
Selenium	613	650	619	627	3	1189	1875	1370	1478	24
Thallium	9.23	10.7	12.2	10.7	14	44.7	44.7	49.4	46.3	6
Zinc	80.0	70.5	74.9	75.1	6	1606	1496	1524	1542	4

* Metal data is in micrograms per liter (except for Hg, which is in nanograms/liter)

ND - Not Detected

NA - Not Applicable

RSD- Relative Standard Deviation (also called the coefficient of variation)

Table 13. QA/QC ANALYTICAL RESULTS FOR LABORATORY SAMPLE SPLITS - SEMI-VOLATILES

Compound	Leachate Sample 17			Compound	Leachate Sample 17		
	17a (ug/l)	17b (ug/l)	RPD		17a (ug/l)	17b (ug/l)	RPD
1 N-Nitrosodimethylamine	<100	<100	NA	35 Nitroaniline, 3-	<500	<500	NA
2 Phenol	230	390	25.8	36 Acenaphthene	<100	<100	NA
3 Aniline	<100	<100	NA	37 Dinitrophenol, 2,4-	<500	<500	NA
4 Bis(2-Chloroethyl)Ether	<100	<100	NA	38 Nitrophenol, 4-	<500	<500	NA
5 Chlorophenol, 2-	<100	<100	NA	39 Dibenzofuran	<100	<100	NA
6 Dichlorobenzene, 1,3-	<100	<100	NA	40 Dinitrotoluene, 2,4-	<100	<100	NA
7 Dichlorobenzene, 1,4-	<100	<100	NA	41 Dinitrotoluene, 2,6-	<100	<100	NA
8 Benzyl Alcohol	<100	<100	NA	42 Diethylphthalate	<100	<100	NA
9 Dichlorobenzene, 1,2,-	<100	<100	NA	43 Chlorophenyl-phenylether, 4-	<100	<100	NA
10 Methylphenol, 2-	<100	<100	NA	44 Fluorene	<100	<100	NA
11 Bis(2-chloroisopropyl)Ether	<100	<100	NA	45 Nitroaniline, 4-	<500	<500	NA
12 Methylphenol, 4-	260	300	7.14	46 Dinitro-2-Methylphenol, 4,6-	<500	<500	NA
13 N-Nitroso-Di-n-Propylamine	<100	<100	NA	47 N-Nitrosodiphenylamine(1)	<100	<100	NA
14 Hexachloroethane	<100	<100	NA	48 Bromophenyl-Phenylether, 4-	<100	<100	NA
15 Nitrobenzene	<100	<100	NA	49 Hexachlorobenzene	<100	<100	NA
16 Isophorone	<100	<100	NA	50 Pentachlorophenol	<100	<100	NA
17 Nitrophenol,2-	<100	<100	NA	51 Phenanthrene	<500	<500	NA
18 Dimethylphenol, 2,4-	<100	<100	NA	52 Anthracene	<100	<100	NA
19 Benzoic Acid	4400	4300	1.15	53 Di-n-Butylphthalate	23 J	33 J	17.9
20 Bis(2-Chloroethoxy)Methane	<100	<100	NA	54 Fluoranthene	<100	<100	NA
21 Dichlorophenol, 2,4-	81 J	110	15.2	55 Benzidine	<1000	<1000	NA
22 Trichlorobenzene, 1,2,4-	<100	<100	NA	56 Pyrene	<100	<100	NA
23 Naphthalene	<100	<100	NA	57 Butylbenzylphthalate	<100	<100	NA
24 Chloroaniline, 4-	<100	<100	NA	58 Dichlorobenzidine, 3,3-	<200	<200	NA
25 Hexachlorobutadiene	<100	<100	NA	59 Benzo(a)Anthracene	<100	<100	NA
26 Chloro-3-Methylphenol, 4-	<100	<100	NA	60 Bis(2-Ethylhexyl)Phthalate	<100	<100	NA
27 Methylnaphthalene, 2-	<100	<100	NA	61 Chrysene	<100	<100	NA
28 Hexachlorocyclopentadiene	<100	<100	NA	62 Di-n-Octyl Phthalate	<100	<100	NA
29 Trichlorophenol, 2,4,6-	<100	<100	NA	63 Benzo(b)Fluoranthene	<100	<100	NA
30 Trichlorophenol, 2,4,5-	<500	<500	NA	64 Benzo(k)Fluoranthene	<100	<100	NA
31 Chloronaphthalene, 2-	<100	<100	NA	65 Benzo(a)Pyrene	<100	<100	NA
32 Nitroaniline, 2-	<500	<500	NA	66 Indeno(1,2,3-cd)Pyrene	<100	<100	NA
33 Dimethyl Phthalate	<100	<100	NA	67 Dibenz(a,h)Anthracene	<100	<100	NA
34 Acenaphthylene	<100	<100	NA	68 Benzo(g,h,i)Perylene	<100	<100	NA

J - estimated value
J* - calculated using at least one estimated value
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample

NA - Not Applicable
RPD- Relative Percent Difference
(|DUP1 - DUP2| / (DUP1 + DUP2)) X 100
where DUP1 is one duplicate and DUP2 is the other

Table 15 presents the results of laboratory blank analysis for TOC. The laboratory split all the samples submitted for analyses by SAIC, including the field blanks. The data in the table are based on three replicates. Based on this data and the data in Tables 12 through 14, analytical precision is very good.

The laboratory also analyzed samples of known concentrations, or spikes, to calibrate and check analytical accuracy. Table 16 presents the results of this analysis for metals. The high spike levels were at five times the low spike levels for respective elements. The percent recovery results are very good, with the exception of arsenic in Sample No. 3. The reason for the high percent recoveries for this compound is not known.

Table 17 presents the spike recovery results for COD and cyanide. The percent recoveries are again very good. Table 18 presents the spike recovery results for TOC. These results are also very good.

Laboratory spiked sample analyses for volatile organic compounds are not presented because recovery data were lost during the dilution of the highly contaminated samples. Extractable surrogate spikes added (50-100 ppb) were not detected at the lowered detection limits. In the absence of spiked sample analyses, field duplicates can be used to assess the accuracy of the laboratory methods for organic analysis. These data were reviewed above and indicate that overall laboratory accuracy is of acceptable quality.

Table 15. QA/QC ANALYTICAL RESULTS FOR LABORATORY SAMPLE SPLITS - TOC

Sample No.	Mean mg/l	Standard Deviation	% Relative Standard Deviation (CV)
1	2,300	208	9.0
2	2,386	190	8.0
3	2,004	374	18.7
4	2,278	142	6.2
5	4	3	75
7	1,018	155	15.2
8	11,750	978	8.3
9	309	81	26.2
10	4,078	886	21.7
11	1,077	149	13.8
12	4	3	75
14	4,909	405	8.3
15	6,602	850	12.9
16	2,453	178	7.3
17	764	72	9.4
18	672	65	9.7
19	195	57	29.2
20	1,579	166	10.5
21	3	2	67

Table 16. QA/QC ANALYTICAL RESULTS FOR LABORATORY SURROGATE SPIKES - TRACE METALS

	Sample No. 3					
Element	Low Spike Added (ug)	Low Spike Recovered (ug)	% Recovery	High Spike Added (ug)	High Spike Recovered (ug)	% Recovery
Silver	0.05	0.06	120%	0.25	0.30	120%
Arsenic	3	27	900%	15.0	38.1	254%
Beryllium	0.10	0.082	82%	0.50	0.50	100%
Cadmium	0.050	0.039	78%	0.25	0.31	124%
Chromium	0.50	0.45	90%	2.5	3.1	124%
Copper	0.20	0.24	120%	1.0	1.1	110%
Nickel	10.0	9.8	98%	50	63	126%
Lead	0.50	0.55	110%	2.5	3.1	124%
Antimony	1.0	1.2	120%	5.0	5.5	110%
Selenium	3.0	5.6	187%	15.0	16.7	111%
Thallium	0.50	0.45	90%	2.5	2.3	92%
Zinc	2	1.7	85%	10	9.1	91%

(Continued)

Table 16. (Continued)

	Sample No. 1					
Element	Low Spike Added (ug)	Low Spike Recovered (ug)	% Recovery	High Spike Added (ug)	High Spike Recovered (ug)	% Recovery
Silver	0.50	0.74	148%	2.5	2.9	116%
Arsenic	20.0	22.5	113%	100	143	143%
Beryllium	0.50	0.54	108%	1.0	1.25	125%
Cadmium	2.0	1.8	90%	10.0	9.4	94%
Chromium	100	112	112%	500	512	102%
Copper	50	38	76%	250	197	79%
Nickel	500	551	110%	2,500	2,402	96%
Lead	50	39	78%	250	277	91%
Antimony	20.0	24.4	122%	100	55	55%
Selenium	20.0	12.4	62%	100	46	46%
Thallium	2.0	1.5	77%	10.0	9.9	99%
Zinc	100	91	91%	500	465	93%

Table 17. QA/QC ANALYTICAL RESULTS FOR LABORATORY SURROGATE SPIKES - COD AND CYANIDE

Parameter/Sample I.D.		True Value	Recovered Value	% Recovery
COD				
	WP782 #3	15.6	13.0	83
	WP782 #3	15.6	17.4	111
Cyanide				
	WP179 #5	0.22	0.20	91
	WP179 #5	0.22	0.21	95
	WP284 #2	1.52	1.39	91

Table 18. QA/QC ANALYTICAL RESULTS FOR LABORATORY SURROGATE SPIKES - TOC

Leachate Sample	Unspiked Value	Spike	Spiked Value	% Recovery
11	1,077	1,000	2,062	99.3
11	1,077	1,500	2,600	100.9
17	764	500	1,284	101.6

SECTION 4

STUDY FINDINGS

Analytical results for the leachates sampled during this study are statistically summarized and discussed in Section 4.1. Based on this analytical and statistical evaluation, three synthetic leachate formulas are proposed in Section 4.2.

4.1 ANALYTICAL RESULTS AND STATISTICAL EVALUATION

The leachate samples collected from the 13 active hazardous waste disposal sites were analyzed for 35 volatile, 68 semi-volatile, and 13 metal priority pollutants. These constituents are respectively listed in Appendix Tables A-1, A-2, and A-3. In addition, the matching of the GC/MS spectra with library spectra identified 102 non-priority pollutant compounds and families of compounds. The compounds are listed in Appendix Table A-4. The results of the leachate sample analyses for the compounds at each site are presented by organic class in Appendix Tables B-1 (organic acids), B-2 (oxygenated/heteroatomic hydrocarbons), B-3 (halogenated hydrocarbons), B-4 (organic bases), B-5 (aromatic hydrocarbons), and B-6 (aliphatic hydrocarbons). The six general classes of organic compounds are frequently used to discuss the compatibility of hazardous waste with various containment liners. Compounds within the individual classes are listed alphabetically. Appendix Table B-7 presents the analytical results for metals, pH, Eh, conductivity, temperature, total cyanide, COD, and TOC. The analytical results for duplicate samples collected at Sites 1, 4, and 7 are averaged for all parameters.

The respective statistical summaries of the organic classes and compounds in Appendix Tables B-1 through B-7 are presented in Table 19 (organic acids), Table 20 (oxygenated/heteroatomic hydrocarbons), Table 21 (halogenated hydrocarbons), Table 22 (organic bases), Table 23 (aromatic hydrocarbons), and Table 24 (aliphatic hydrocarbons). Table 25 presents the statistical summary for metals, pH, Eh, temperature, total cyanide, TOC, and COD. The tables present, for each parameter, the range of detected values in micrograms per liter (ug/l), the mean concentration (ug/l), the standard deviation of the mean concentration, the mean mole fraction percentage, and the number of sites at which the organic compound or metal was detected in the leachate samples. A value of zero was assigned when the parameter was not detected in the leachate sample of a site. The compounds in Tables 19 through 24, representing the six classes of organics, are listed in order of decreasing total mean mole fraction percentage. The analytical results for the aqueous (instead of the oil) fraction of the sample collected at Site 9 were used in the statistical

Table 19. STATISTICAL DATA FOR ORGANIC ACIDS

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Phenol	2400	110000	21600	28700	13	11.76
2 Methylphenol, 4-	110	47000	11400	14300	12	5.40
3 Benzoic Acid	3090J	20600	7120	7420	8	5.27
4 Butanoic Acid	2400	49400	6120	13500	4	3.52
5 Propanoic Acid, 2-Methyl-	3660	17000	2580	4810	4	2.38
6 Pentanoic Acid	4180	21500	3230	6850	3	2.06
7 Methylphenol, 2-	94J'	24000	4780	6940	10	2.01
8 Alkanoic Acid	1120	50100	3940	13300	2	1.42
9 Hexanoic Acid	3600	39700	3330	10500	2	1.13
10 Dimethylphenol, 2,4-	30J'	12000	2640	3690	9	0.83
11 Phenylacetic Acid	1660	6400	1440	2120	5	0.67
12 Phenol, 2,6-bis(1,1-dimethylethyl)-4-Methyl-	--	26700	2050	7110	1	0.39
13 Hexanoic Acid, 2-Ethyl-	255	4530	810	1260	6	0.29
14 Pentanoic Acid, 4-Methyl-	1180	2630	293	744	2	0.24
15 Phenol, 4-(Methylthio)-	--	770	59.2	205	1	0.21
16 Octanoic Acid	--	9440	726	2520	1	0.18
17 Butanoic Acid, 2-Methyl-	510	2610	420	888	3	0.18
18 Dichlorophenol, 2,4-	86.8J'	2900	471	928	4	0.16
19 Phenol, 2,4,6-Trimethyl-	--	5720	440	1520	1	0.14

-- - Compound was detected at only one site
J - estimated value
J' - calculated using at least one estimated value

(Continued)

Table 19. (Continued)

Compound	Range Of Detected Compounds		Mean	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
	Min (ug/l)	Max (ug/l)	(ug/l)			
20 Phenylpropanoic Acid	27.2	2230	274	613	4	0.10
21 Pentachlorophenol	--	1900	146	506	1	0.09
22 Propanoic Acid, 2,2-Dimethyl-	--	228	17.5	60.8	1	0.09
23 Benzoic Acid, 4-Chloro	--	8220	632	2190	1	0.08
24 Trichlorophenol, 2,4,6-	--	3860	297	1030	1	0.06
25 Acetic Acid, (2,4-Dichlorophenoxy)-	--	898	69.1	239	1	0.05
26 Trichlorophenol, 2,4,5-	--	3440	265	917	1	0.05
27 Phenol, 2,5-Dichloro	--	2760	212	735	1	0.05
28 Naphthalene Carboxylic Acid, 1-	--	618	47.5	165	1	0.04
29 Phenol, 4,4'-Methylenebis-	--	5540	426	1480	1	0.04
30 Chlorophenol, 2-	--	1790	138	477	1	0.04
31 Phenol, 2-Chloro-	--	1090	83.8	290	1	0.02
32 Benzoic Acid, 4-(1,1-Dimethylethyl)-	--	675	51.9	180	1	0.01
33 Phenylacetic Acid, 4-Methoxy-	--	710	54.6	189	1	0.01
34 Benzoic Acid, 3,4-Dichloro-	--	1210	93.1	322	1	0.01
35 Phenol, 3-(1,1-Dimethylethyl)-	--	525	40.4	140	1	0.01
36 Benzene-1,2-dicarboxylic Acid	--	32.5	2.5	8.66	1	0.01
37 Phenol, 2,5-Dimethyl-	--	318	24.5	84.7	1	0.01
38 Chloro-3-Methylphenol, 4-	--	36J'	2.77	9.59	1	.00
						39.01

-- - Compound was detected at only one site
J - estimated value
J' - calculated using at least one estimated value

Table 20. STATISTICAL DATA FOR OXYGENATED/HETEROATOMIC HYDROCARBONS

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Acetone	344	77500	23200	24600	13	16.51
2 Butanone, 2-	62	42900	13600	15800	12	6.83
3 Benzyl Alcohol	1740J'	68000	11100	22100	6	4.57
4 Hexanone, 2-	17J	17200	4610	5820	13	1.92
5 Pentanol, 4-Methyl-, 2	2450	33000	2730	8760	2	0.95
6 Cyclopentanol, 2-Methyl	1130	17800	1460	4730	2	0.56
7 Ethane, 1,1'-Oxybis[2 Methoxy-	540	16600	1320	4410	2	0.50
8 Ethanol, 2-Butoxy-	1560	3740	408	1050	2	0.43
9 Methyl-2-Pentanone, 4-	9J	3790	775	1290	11	0.42
10 Ethanol, 2-(2-Butoxyethoxy)-	940	10800	1290	3050	3	0.42
11 Cyclohexanone	1650	3930	708	1380	3	0.29
12 Benzene-1,2-dicarboxylic Acid Anhydride	1020	6720	917	2010	3	0.27
13 Pentanediol, 2,2,4-Trimethyl-, 1,3-	810	5490	485	1460	2	0.27
14 Isophorone	--	15000	1150	4000	1	0.27
15 Propanediol, 2,2-Dimethyl-,1,3-	588	2440	233	656	2	0.26
16 Phosphoric Acid Tributylester	--	18200	1400	4850	1	0.22
17 Hexanol, 2-Ethyl-,1-	434	1860	222	508	3	0.17
18 Propanol, 1-(2-Methoxy-1-Methylethoxy)-, 2-	112	1550	128	412	2	0.16
19 Tetrathiepane, 1,2,4,6-	--	3020	232	805	1	0.15
20 Ethanol, 1-(2-Butoxyethoxy)-	1230	8860	776	2360	2	0.12

-- - Compound was detected at only one site

J - estimated value

J' - calculated using at least one estimated value

(Continued)

Table 20. (Continued)

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
21 Ethanol, 2,2'- Thiobis-	--	3930	302	1050	1	0.09
22 Benzaldehyde, 4-Hydroxy-3-Methoxy-	--	770	59.2	205	1	0.06
23 Isoindole-1,3(2H)-Dione, 1H-	--	1490	115	397	1	0.06
24 Naphtho[1,8-CD]Pyran-1,3-Dione, 1H, 3H	31.2	692	55.6	184	2	0.05
25 Methane, Sulfonylbis-	--	1560	120	416	1	0.05
26 Pentanediol, 2-Methyl-, 2,4-	--	2660	205	709	1	0.04
27 Di-n-Butylphthalate	22.5J'	996	216	299	9	0.04
28 Ethanol,2-(2-Ethoxyethoxy)-	--	1210	93.1	322	1	0.03
29 Ethanol, 2-[2-(2-Ethoxyethoxy)Ethoxy]-	--	1560	120	416	1	0.02
30 Anthracenedione, 9,10-	--	750	57.7	200	1	0.02
31 Isoindole-1,3(2H)-Dione, 3A,4,7,7A-Tetrahydro-,cis-,1H-	--	1630	125	434	1	0.02
32 Phosphineoxide, Triphenyl-	--	2390	184	637	1	0.02
33 Propan-2-ol, 2-Phenyl-	226	402	48.3	118	2	0.01
34 Cyclohexan-1,2-dicarboxylic Acid Anhydride	--	1030	79.2	274	1	0.01
35 Alkanol	--	1020	78.5	272	1	0.01
36 Bis(2-Ethylhexyl)Phthalate	--	1480	114	394	1	0.01
37 Dimethyl Phthalate	--	820	63.1	219	1	0.01
38 Methyl Acetophenone	--	131	10.1	34.9	1	.00
39 Di-n-Octyl Phthalate	--	31	2.38	8.26	1	.00
						35.82

-- - Compound was detected at only one site

J - estimated value

J' - calculated using at least one estimated value

Table 21. STATISTICAL DATA FOR HALOGENATED HYDROCARBONS

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Methylene Chloride	19	56800	14100	17300	13	6.75
2 Dichlorobenzene, 1,2,-	173J'	46000	3550	12200	2	1.01
3 Trichloroethane, 1,1,1-	37	22000	1830	5830	5	0.92
4 Trichloroethylene	13.2J'	11300	2040	3260	11	0.71
5 Chloroform	2.5J'	7250	1940	2600	10	0.67
6 Chlorobenzene	107	2480	480	815	6	0.23
7 Dichloroethane, 1,2-	--	9040	695	2410	1	0.17
8 Dichloroethane, 1,1-	47	1620	182	443	4	0.15
9 Dichlorobenzene, 1,4-	186J'	6300	499	1680	2	0.14
10 Tetrachloroethylene	4.75J'	1800	430	579	7	0.11
11 Trans-1,2-Dichloroethylene	11J	1610	166	428	5	0.06
12 Dichlorobenzene, 1,3-	150J'	990	87.7	264	2	0.05
13 Carbon Tetrachloride	--	879	67.6	234	1	0.03
14 Trichloroethane, 1,1,2-	42J	231	21	61.6	2	0.01
15 Dichloropropane, 1,2-	82J	186	33.2	64.4	3	0.01
						11.01

-- - Compound was detected at only one site
J - estimated value
J' - calculated using at least one estimated value

Table 22. STATISTICAL DATA FOR ORGANIC BASES

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Aniline	14200	56000	7780	16400	3	2.92
2 Acetamide, N, N-Dimethyl-	--	13800	1060	3680	1	1.07
3 Chloroaniline, 4-	12000	15500	2120	5010	2	0.97
4 Pyrrolidinone, 1-Methyl-,2-	360	14400	1420	3870	3	0.60
5 Isoquinoline	--	3020	232	805	1	0.29
6 Azepin-2-One, Hexahydro-, 2H-	--	7410	570	1970	1	0.26
7 Pyridine	--	11500	885	3060	1	0.23
8 Pyridine, 2-Chloro-	3880	6200	775	1870	2	0.18
9 Benzenesulfonamide, 4-Methyl	202	6020	661	1590	5	0.16
10 Benzene, 1,3-Diamino-4-Methyl-	--	2480	191	661	1	0.14
11 Benzene, 1,4-Diamino-	--	1940	149	517	1	0.12
12 Benzene, 1,2-Diamino-	--	835	64.2	223	1	0.05
13 Benzamide	--	1500	115	400	1	0.05
14 Aniline, 2,3-Dichloro-	--	1150	88.5	306	1	0.05
15 Naphthalene, 2-Amino	--	942	72.5	251	1	0.04
16 Aniline, 2-Methoxy	--	515	39.6	137	1	0.03
17 Benzenesulfonamide, 2-Methyl	--	114	8.77	30.4	1	0.03
18 Pyridinamine, 2-	--	560	43.1	149	1	0.02
19 Morpholine, 4-Ethyl-	--	520	40	139	1	0.01
						7.21

-- - Compound was detected at only one site

Table 23. STATISTICAL DATA FOR AROMATIC HYDROCARBONS

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Toluene	31	33600	8340	11100	13	4.25
2 Total Xylenes	60	5160	1540	1720	11	0.81
3 Naphthalene	26.5J'	5200	468	1380	4	0.30
4 Benzene	8.65J'	720	303	241	12	0.18
5 Ethylbenzene	16J	1100	334	365	10	0.16
6 Trimethyl Benzene, Isomer	143	300	34.1	85.6	2	0.10
7 Methylnaphthalene, 2-	120J	3400	271	904	2	0.09
8 Benzene, 1,2,3-Trimethyl-	--	2240	172	597	1	0.05
9 Phenanthrene	--	300	23.1	79.9	1	0.02
10 Benzene, 2-Ethyl-1,4-Dimethyl-	--	965	74.2	257	1	0.02
11 Styrene	--	637	49	170	1	0.02
12 Benzene, 1-Ethyl-2-Methyl-	--	346	26.6	92.2	1	0.01
13 Acenaphthylene	--	150J	11.5	40.0	1	0.01
14 Tetramethyl Benzene, Isomer	--	255	19.6	67.9	1	0.01
15 Benzene, Propyl-	--	176	13.5	46.9	1	0.01
						6.05

-- - Compound was detected at only one site
J - estimated value
J' - calculated using at least one estimated value

Table 24. STATISTICAL DATA FOR ALIPHATIC HYDROCARBONS

Compound	Range Of Detected Compounds Min (ug/l)	Max (ug/l)	Mean (ug/l)	Std Dev	Number of Sites Where Compound Was Detected	Mean Mole Fraction (X100)
1 Bicyclo[2.2.1]Hept-2-ene, 1,7,7-Trimethyl-	--	17300	1330	4610	1	0.41
2 n-Alkanes [C]*	--	9540	734	2540	1	0.12
3 Heptane, 2,2,4,6,6-Pentamethyl-	--	4760	366	1270	1	0.09
4 Heptadecane	575	5440	463	1440	2	0.08
5 n-Alkanes [A]*	--	3380	260	901	1	0.07
6 n-Alkanes [D]*	--	3740	288	997	1	0.04
7 n-Alkanes [B]*	--	2700	208	719	1	0.04
8 Cyclobutene, 2-Propenylidene-	--	75	5.77	20.0	1	0.03
						0.89

-- - Compound was detected at only one site

* n-Alkanes are catagorized on the basis of retention time as follows:

n-Alkanes [A]	10:00-14:59 minutes
n-Alkanes [B]	15:00-19:59 minutes
n-Alkanes [C]	20:00-24:59 minutes
n-Alkanes [D]	25:00-29:59 minutes

Table 25. STATISTICAL DATA FOR METALS, pH, Eh, CONDUCTIVITY, TOTAL CYANIDE, TOC, AND COD

Parameter	Range Of Detected Constituent				Number of Sites Where Constituent Was Detected	Mean Mole Fraction (X100)
	Min	Max	Mean	Std Dev		
Metal*						
1 Silver	0.3	32.8	6.55	9.56	13	0.0249
2 Arsenic	458	129600	13097.08	33868.32	10	31.9456
3 Beryllium	0.2	7.4	0.81	1.96	6	0.0904
4 Cadmium	0.7	102	18.74	28.25	13	0.1572
5 Chromium	0.2	1734	280.54	558.80	13	2.2826
6 Copper	2.3	17030	1885.07	4525.28	13	13.0760
7 Mercury	45	39300	4973.04	10308.36	12	0.0101
8 Nickel	17.3	67110	6416.95	17609.15	13	22.5979
9 Lead	0.3	1006	115.58	263.09	13	0.3740
10 Antimony	13	5240	522.35	1367.79	11	3.9792
11 Selenium	221	3488	1167.88	890.25	13	16.9132
12 Thallium	9.4	156	36.92	45.62	11	0.1223
13 Zinc	5.12	24510	2512.77	6403.20	13	8.4268
						100
pH**	7.1	9.3	8.2	0.857		
Eh** (volts)	-0.343	-0.093	-0.226	0.126		
Conductivity** (micromhos/cm)	4,250	12,000	14694	6588		
Temperature** (°C)	19.9	32	26.7	6.2		
Total Cyanide*** (mg/l)	0.01	55	9.93	17.85	9	
COD*** (mg/l)	1950	23300	10217	6475		
TOC*** (mg/l)	195	11750	3097	3071		

* Metal Data is in micrograms per liter (except for Hg, which is in nanograms per liter)

** Statistical data does not include sites where no measurement was taken

*** All samples were analyzed for Total Cyanide, TOC,and COD evaluation. The analytical data from specific analytical measurements (metals, cyanide, TOC, organics, etc.) are presented in the number of significant figures allowed by the procedure. Range, mean, and standard deviation are rounded conservatively to three significant figures. The mean mole fraction percentage is rounded to the closest hundreth.

The analytical findings and statistical evaluations are discussed in Sections 4.1.1 (TOC), 4.1.2 (organics), and 4.1.3 (inorganics). Section 4.1.4 discusses the attempt to correlate the leachate characteristics with other site characteristics, i.e., disposed waste, climate, and geography.

4.1.1 Evaluation of Total Organic Carbon (TOC) Data

During the formulation of this study's analytical program requirements, GC/MS analytical methodology was used to identify and quantify the constituents present in the leachate samples because of its capabilities to detect volatile and semi-volatile priority pollutant and non-priority pollutant compounds. However, a yardstick with which to gauge the success of the analytical program in achieving maximum identification of constituents was necessary. Therefore, the determination of analytical TOC was also incorporated into the program. This TOC represents the total of all organic compounds present within a leachate sample, as determined by a single analytical procedure. Ideally, a calculated TOC based on concentrations of the detected organic compounds in a leachate sample should equal the analytical TOC. Thus, the sum of the calculated TOC values, when presented as a percentage of the sample's analytical TOC, provides a gauge of program effectiveness in identifying all organic compounds present.

Table 26 presents the analytical TOC of leachate samples from each site and the percentage of this TOC which is accounted for by the calculated TOC. The percentage of analytical TOC which is accounted for by the total detected organic compounds is less than 10 percent for 11 of the 13 sites and less than 5 percent for 6 of the 13 sites. The leachate samples from Sites 5 and 9, for which a substantial percentage of the analytical TOC is accounted for (40.4% and 59.5%, respectively) have much lower analytical TOC values than the other leachate samples examined. The low percentages of analytical TOC accounted for by the detected compounds probably reflect substantial concentrations of non-volatile low or high molecular weight organics, or other constituents which did not extract or chromatograph well. Other factors which could lead to incomplete qualitative and quantitative organic results include:

- Incomplete extraction of water soluble semi-volatiles may occur during sample preparation. In addition, non-volatile materials (e.g., large molecular weight or polymeric organics) may not chromatograph successfully and may not display coherent peaks. This class of materials would be incompletely characterized under the conditions used in this study for extracton and GC/MS analysis.

Table 26. PERCENT OF ANALYTICAL TOTAL ORGANIC CARBON (TOC) ACCOUNTED FOR BY LEACHATE SAMPLE ANALYSIS

Site	TOC (mg/l)	Priority Pollutants (%)		Non-Priority Pollutants (%)	Total (%)
		Volatile	Semi-Volatile		
1	2343	1.734	2.86	2.176	6.77
2	2004	1.565	0.876	5.86	8.30
3	2278	0.1886	3.94	1.951	6.08
4	718	0.659	0.604	0.2917	1.55
5	195	34.4	1.137	4.89	40.43
6	1579	0.167	2.392	0.487	3.05
7	1048	1.90	2.20	1.939	6.04
8	11750	0.00393	0.743	0.1820	0.93
9	309	20.98	18.12	20.41	59.51
10	4078	2.075	1.718	0.468	4.26
11	4909	1.995	3.06	0.500	5.56
12	6602	1.510	1.551	0.3520	3.41
13	2453	0.314	1.049	1.020	2.38

- The combination of sample concentration (very high in organics) as well as sample complexity (a large number of diverse compounds) may contribute to misidentification of compounds. The problem of misidentification is probably relatively minor because of the technique of computer matching mass spectrometric results. However, GC peak overlap was frequently observed, even when the peak components were identified via mass spectrometry, and concentration errors were difficult to avoid.

- The GC/MS methodology used in this study was highly sensitive. The leachate samples contained a large organic component. In order to keep instrumental readings on scale, the samples required large dilutions, which increased the minimum detection limits. As a result, many trace constitutents which may have been detectable in an undiluted sample were rendered undetectable.

Approximately 96% of the overall organic fraction of the leachate samples is not accounted for by the TOC calculated from the detected organic compounds. This inability to account for a substantial percentage of the analytical TOC with detected compounds in nearly all of the leachate samples suggests that a synthetic leachate formulated according to this study's detected compounds alone may not be fully representative of most leachates. However, suggestions will be made in Section 4.2, Leachate Formulation, with respect to how to represent the unaccounted analytical TOC in a synthetic leachate formula.

4.1.2 Evaluation of Organic Data

As presented in Tables 19 through 24, the total mean mole fraction percentage represented by each of the six classes of organics are, in decreasing order: organic acids - 39.0%, oxygenated/heteroatomic hydrocarbons - 35.8%, halogenated hydrocarbons - 11.0%, organic bases - 7.2%, aromatic hydrocarbons - 6.0%, and aliphatic hydrocarbons - 0.9%. In general, classes of organics containing compounds with relatively high aqueous solubilities account for higher mean mole fraction percentages than do classes of organics containing compounds with lower aqueous solubilities For example, the mean mole fraction percentages accounted for by the organic acids (39.0%) and the oxygenated/heteroatomic compounds (35.8%) are much greater than those accounted for by the aromatic hydrocarbons (6.0%) and the aliphatic hydrocarbous (0.9%).

Within a given class of organics, the compounds accounting for the highest mean mole fraction percentages tend to have higher aqueous solubilities than compounds accounting for lower mean mole fraction percentages or compounds which were not detected. Of course, the amount of a compound disposed at a site will also affect its concentration in leachate.

The statistical data for the organic class of each respective table is summarized in the next six subsections. Pesticide and high performance liquid chromatography analytical results are discussed in Section 4.1.2.7.

4.1.2.1 Organic Acids (Table 19)

Of the 39.0 total mean mole fraction percentage represented by organic acids, 11.8% is phenol, 9.5% is contributed by 17 substituted phenols, 5.4% is benzoic acid and 4 substituted benzoic acids, and 12.3% is alkanoic acids. The compounds accounting for the greatest mean mole fraction percentages are phenol (11.8%), 4-methylphenol (5.4%), benzoic acid (5.3%), butanoic acid (3.5%), and 2-methylpropanoic acid (2.4%). The compounds detected in leachate samples from the greatest number of the sites are phenol (13 sites), 4-methylphenol (12 sites), 2-methylphenol (10 sites), 2,4-dimethylphenol (9 sites), and benzoic acid (8 sites). All of the five organic acids which account for the greatest mean mole fraction percentages were also detected at the greatest number of sites, except for butanoic and 2-methylpropanoic acid. Phenol ranks first in the mean mole fraction percentage and was detected in leachate samples from all 13 sites.

4.1.2.2 Oxygenated/Heteroatomic Hydrocarbons (Table 20)

Of the 35.8 total mean mole fraction percentage represented by oxygenated/heteroatomic hydrocarbons, 16.5% is acetone, 9.2% is common ketone solvents (2-butanone, 4-methyl-2-pentanone, and 2-hexanone), and 8.1% is contributed by 16 different alcohols. The compounds accounting for the greatest mean mole fraction percentages are acetone (16.5%), 2-butanone (6.8%), benzyl alcohol (4.6%), 2-hexanone (1.9%), and 4-methyl-2-pentanol (1.0%). The compounds detected in leachate samples from the greatest number of sites are acetone (13 sites), 2-hexanone (13 sites), 2-butanone (12 sites), 4-methyl-2-pentanone (11 sites) and di-n-butylphthalate (9 sites). Of the five oxygenated/heteroatomic hydrocarbons accounting for the greatest mean mole fraction percentages, only acetone, 2-butanone, and 2-hexanone are also among the five compounds detected at the greatest number of sites. Acetone ranks first in the mean mole percentage and was detected in leachate samples from all 13 sites.

4.1.2.3 Halogenated Hydrocarbons (Table 21)

Of the 11.0 total mean mole fraction percentage represented by halogenated hydrocarbons, 6.8% is methylene chloride, 1.4% is contributed by four chlorinated benzenes, and 2.8% is from ten chlorinated alkanes/alkenes. The compounds accounting for the greatest mean mole fraction percentages are methylene chloride (6.8%), 1,2-dichlorobenzene (1.0%), 1,1,1-trichloroethane (0.9%), trichloroethylene (0.7%), and chloroform (0.7%). The compounds detected in leachate samples from the greatest number of sites are methylene chloride (13 sites), trichloroethylene (11 sites), chloroform (10 sites), tetrachloroethylene (7 sites), and chlorobenzene (6 sites). Of the five halogenated hydrocarbons accounting for the greatest mean mole fraction percentage, only methylene chloride, trichloroethylene, and chloroform are also among the five compounds detected at the greatest number of sites. Methylene chloride ranks first in the mean mole fraction percentage and was detected in leachate samples from all 13 sites.

4.1.2.4 Organic Bases (Table 22)

Of the 7.2 total mean mole fraction percentage represented by organic bases, 2.9% is aniline and 1.4% is contributed by six substituted anilines. The compounds accounting for the greatest mean mole fraction percentages are aniline (2.9%), N,N-dimethylacetamide (1.1%), 4-chloroaniline (1.0%), 1-methyl-2-pyrrolidinone (0.6%) and isoquinoline (0.3%). No single organic base was detected at greater than half of the sites. The compounds detected at the greatest number of sites were 4-methylbenzenesulfonamide (5 sites), aniline (3 sites), 1-methyl-2-pyrrolidinone (3 sites), 4-chloroaniline (2 sites), and 2-chloropyridine (2 sites). The remaining fourteen organic bases were each detected at only one site. Although 4-methylbenzenesulfonamide ranks first in the number of sites at which it was detected, it ranks ninth in the mean mole fraction percentage represented. Although aniline ranks first by a large margin in the mean mole fraction percentage represented, it was detected in the leachate samples of only 3 of the 13 sites sampled.

4.1.2.5 Aromatic Hydrocarbons (Table 23)

Of the 6.0 total mean mole fraction percentage represented by aromatic hydrocarbons, 4.2% is toluene and 1.4% is benzene and alkyl benzenes other than toluene. The compounds accounting for the greatest mean mole fraction percentages are toluene (4.2%), total xylenes (0.8%), naphthalene (0.3%), benzene (0.2%); and ethylbenzene (0.2%). The aromatic hydrocarbons detected in leachate samples from the greatest number of sites are toluene (13 sites), benzene (12 sites), total xylenes (11 sites), ethylbenzene (10 sites) and naphthalene (4 sites). Toluene ranks first by a large margin in the mean mole fraction percentage represented and was detected in leachate samples from all 13 sites.

4.1.2.6 Aliphatic Hydrocarbons (Table 24)

Aliphatic hydrocarbons account for a total mean mole fraction of only 0.9% and no single compound is predominant.

4.1.2.7 Pesticide and High Performance Liquid Chromatography Analytical Results

A GC/ECD analysis for PCBs and chlorinated pesticides was carried out on the leachate sample from Site 12, which is a site accepting PCB-contaminated wastes. Seven different PCBs and pesticides were detected in leachate from Site 12. In order of concentration (ug/l) the compounds are: endosulfan sulfate (14.8), endrin ketone (11.4), heptachlor epoxide (8.6), dieldrin (4.5), 4,4'-DDD (2.2), endrin (1.9) and alpha-BHC (1.7). The combined contributions of these substances, in terms of mole fraction percentage of organic compounds of all types (including volatile and semi-volatile organics) is negligible at less than .01 mole fraction percentage. In addition, in terms of TOC measured at Site 12, the above compounds account for only a very small part of the total. The overall contribution of these compounds to synthetic leachate composition cannot be assessed on the basis of data from only one test site. Based on this single case, PCBs and chlorinated pesticides do occur in leachate when they have been deposited in the waste site, but not in significant concentrations.

High performance liquid chromatography was performed on leachate samples and method blanks from all the sites. The HPLC analyses yielded no information regarding identification or quantitation of organic compounds. Therefore, no interpretation of these results is offered in this report.

4.1.3 Evaluation of Inorganic Data

Table 25 presents the data for inorganic parameters (i.e., metallic ions, cyanide, pH, etc.). The analytical results are reliable from the standpoint of quality control (Section 3.4), with the exception of the lack of complete pH and Eh data. Data for these parameters were obtained from only a few sites because of suspected field instrument malfunction.

Liner materials of all types are known to be affected by high or low pH (Section 2). For that reason, pH is an important factor with respect to leachate and liner compatibility. The pH reported during this study ranged from neutral to mildly alkaline.

The metallic ion concentrations of the leachate samples are, in general, in the fractional parts per million (ppm) range or less. Information on landfill liner and chemical compatibility indicates that aqueous solutions of the salts of the detected metal ions have little effect on plastic liner materials even when highly concentrated. For this discussion, one ppm is an arbitrarily selected conservative estimate of metallic ion concentration below which reaction with liner material is not anticipated. More than half of the sites (2, 4, 5, 7, 9, 11, and 13) have only one metal in a concentration greater than one ppm. Three sites (1, 3, and 12) have five or more metals at concentrations greater than one ppm. Arsenic and selenium are the most commonly encountered elements (seven sites each) at greater than one ppm, followed closely by nickel, zinc, and copper.

4.1.4 Comparison of Analytical Results With Site Characteristics

One goal of this study was to attempt to correlate the chemical characteristics of the leachates with the climatic region, geographic location, and waste acceptance characteristics of the respective hazardous waste disposal sites. Unfortunately, this objective can not be fully met mainly because of two reasons: 1) detailed information on the waste characteristics of the sites was generally not available and 2) there is not a large enough representation of sites within a particular climatic region, geographic location, or waste acceptance category to draw valid conclusions. Also, in addition to climate and waste type factors, the detected chemical concentrations could have been affected by other factors:

- The quantities of wastes disposed
- The physical forms of the disposed wastes (e.g., solids or liquids, containerized or bulk)

- The procedures by which the leachate was collected, stored, and handled at each site prior to sampling, which affects leachate representativeness

- The effectiveness of any waste site cover or other environmental controls

- Physical characteristics of the surrounding environment, e.g., site-specific precipitation patterns and the assimilative capacity of the site soil.

All of these factors interrelate to affect leachate quality and quantity. Correlations between chemical concentrations and a general category, such as climate or waste type, are difficult to make without complete information on all of the factors. The probable impacts and significance of these factors are discussed below.

Site-specific information on the quantities and types of disposed waste was either not available from the sites or was too general or incomplete. For the most part, however, general information was available regarding the physical forms of the waste. This information is used in the categorization of sites based on waste input, which is explained in more detail later.

Section 3.4.1 discussed the steps taken by the samplers to maximize the representativeness of the leachate samples. However, situations beyond sampling team control at several sites probably decreased sample representation. Good leachate representativeness might not have been obtained from Sites 1, 3, 5, and 6 based on age of the leachates and exposures to the air. The extent of leachate representativeness probably impacted the analytical results for volatile organics. Samples of leachate from Sites 1, 3, and 5 do contain levels of volatile organics lower than those present, for the most part, at other sites. For example, Site 3 leachate samples were taken from a lagoon open to the atmosphere. The site accepted a variety of wastes, both inorganic and organic, as did six other sites. The ratio of TOC at Site 3 to TOC values at most other sites is larger than the ratio of total volatile organics at Site 3 to the total volatile organics at other sites. This might support the hypothesis that volatiles were lost prior to sampling and the leachate sample is, therefore, probably not representative. However, a conclusion can not be made without complete information on characteristics waste types and factors which affect leachate characteristics.

Design, operation, and environmental characteristics of a site can also affect leachate quality. For example, most of the study sites are operating landfills without final cover, although wastes are at times periodically covered with bulk solid wastes or fill. This diversity in exposure to precipitation affects the validity of making comparisons or correlations between sites with respect to leachate quality.

Analytical data at the sites has been compared in an attempt to identify trends, despite the limitations mentioned above. Tables 27, 28, and 29 present the mean concentrations in ug/l of 40 organic compounds found at three or more of the thirteen sites. Inorganic parameters are not included because they are believed to have little impact on liner effectiveness, as noted in Section 2. The sites are grouped within each table based on common factors with respect to either waste type (Table 27), climate (Table 28), or geography (Table 29).

Table 27 presents site data grouped by waste type:

- Group 1, high variety of both inorganic and organic wastes, includes Sites 2, 3, 5, 6, 10, 11, and 13
- Group 2, also high waste variety, but the leachate is expected to be low in organics based on specific waste types and whether the wastes were containerized or disposed in bulk, includes Sites 4, 7, and 9
- Group 3, low waste variety, alkaline inorganics only, includes Site 1
- Group 4, low waste variety, mostly PCB-contaminated materials, includes Site 12
- Group 5, low waste variety, mostly wastewater biological treatment sludge, includes Site 8.

Each site was placed into one of the above groups based on the waste information received from the site contacts. The amount of detail in this information varied greatly between the sites and for the most part was very general.

Three of the five groups represent sites with very specific wastes, i.e., Groups 3 (inorganic alkalines), 4 (PCB-contaminated materials), and 5 (wastewater biological treatment sludge). For the most part, evaluation of the complete analytical data for each of these sites would be more meaningful than an evaluation based on the compounds in Table 27. Wastes at these sites are specific and their chemicals may not be represented among the 40 common compounds. Nevertheless, the data in Table 27 does show fewer of the common chemicals at these sites of low waste variety. However, comparison of Groups 3, 4, and 5 against the other two groups may not be valid because the former groups contain only one site each. For example, Group 5 shows the highest phenol concentration of the five groups. However, even higher concentrations of phenol are found at certain sites in Groups 1 and 2 and were averaged in with the lower concentrations at other sites in these two groups. Leachate from Site 11 in Group 1 actually has the highest phenol concentration.

Group 1 shows greater variety of organic compounds than Group 2, which supports the assignment of the sites to the respective groups. All 40 of the organic compounds are found in Group 1, which includes sites accepting a wide variety of both organic and inorganic wastes. Group 2 includes only

Table 27. ORGANICS DATA BASED ON SITE WASTE

Compound	Mean Concentrations (ug/l) for Site Groupings*				
	1	2	3	4	5
Organic Acids					
Benzoic Acid	7240	1070	15200	11500	11900
Butanoic Acid	11000	800	0	0	0
Butanoic Acid, 2-Methyl-	707	0	510	0	0
Dichlorophenol, 2,4-	447	28.9	0	2900	0
Dimethylphenol, 2,4-	2990	10	1390	12000	0
Hexanoic Acid, 2-Ethyl-	1340	0	1150	0	0
Methylphenol, 2-	5130	8030	2130	0	0
Methylphenol, 4-	16300	1390	4080	23000	1900
Pentanoic Acid	3670	0	0	0	16300
Phenol	27000	4170	25300	16000	38000
Phenylacetic Acid	1040	0	1660	3350	6400
Phenylpropanoic Acid	74.3	269	0	2230	0
Propanoic Acid, 2-Methyl-	3500	1220	5400	0	0
Aromatic Hydrocarbons					
Benzene	367	153	177	720	14
Ethylbenzene	299	197	583	1070	0
Naphthalene	97.1	8.83	178	0	5200
Toluene	8020	10900	8170	11400	109
Total Xylenes	1550	333	3000	5160	60
Organic Bases					
Aniline	8000	4730	31000	0	0
Benzenesulfonamide, 4-Methyl	339	67.3	0	6020	0
Pyrrolidinone, 1-Methyl-,2-	2060	120	3690	0	0

* 1 - High waste variety, both inorganic and organic. Set of 7 sites
2 - High waste variety, but expected low in organics. Set of 3 sites.
3 - Low waste variety, alkaline inorganic wastes only. Set of one site.
4 - Low waste variety, mostly PCB-contaminated materials and wastewater treatment sludge. Set of one site.
5 - Low waste variety, mostly phthalic wastes and wastewater treatment sludge. Set of one site.

(Continued)

Table 27. (Continued)

Compound	Mean Concentrations (ug/l) for Site Groupings*				
	1	2	3	4	5
Halogenated Hydrocarbons					
Chlorobenzene	465	703	132	740	0
Chloroform	634	3010	7250	4470	9
Dichloroethane, 1,1-	321	40.7	0	0	0
Dichloropropane, 1,2-	35.1	0	0	186	0
Methylene Chloride	11700	1590	39600	56800	90
Tetrachloroethylene	511	1.58	1160	849	0
Trans-1,2-Dichloroethylene	25	4.47	1610	347	11
Trichloroethane, 1,1,1-	3300	104	0	394	0
Trichloroethylene	2510	560	6380	850	0
Oxygenated/Heteroatomic Hydrocarbons					
Acetone	25200	16800	16600	57800	344
Benzene-1,2-dicarboxylic Acid Anhydride	146	0	0	6720	4180
Benzyl Alcohol	2710	0	1740	68000	56000
Butanone, 2-	14400	8780	15000	34700	62
Cyclohexanone	753	0	3930	0	0
Di-n-Butylphthalate	84.7	269	996	310	100
Ethanol, 2-(2-Butoxyethoxy)-	2260	0	940	0	0
Hexanol, 2-Ethyl-,1-	266	145	590	0	0
Hexanone, 2-	5020	1890	1860	17200	17
Methyl-2-Pentanone, 4-	1230	475	0	9	17

* 1 - High waste variety, both inorganic and organic. Set of 7 sites

2 - High waste variety, but expected low in organics. Set of 3 sites.

3 - Low waste variety, alkaline inorganic wastes only. Set of one site.

4 - Low waste variety, mostly PCB-contaminated materials and wastewater treatment sludge. Set of one site.

5 - Low waste variety, mostly phthalic wastes and wastewater treatment sludge. Set of one site.

Table 28. ORGANICS DATA BASED ON SITE CLIMATE

Compound	Mean Concentrations (ug/l) for Site Groupings*			
	6	7	8	9
Organic Acids				
Benzoic Acid	9500	6140	8800	3690
Butanoic Acid	0	0	3880	20100
Butanoic Acid, 2-Methyl-	0	170	468	870
Dichlorophenol, 2,4-	475	28.9	580	727
Dimethylphenol, 2,4-	1200	3460	3790	671
Hexanoic Acid, 2-Ethyl-	128	797	306	2120
Methylphenol, 2-	2080	5710	1670	10800
Methylphenol, 4-	5060	13100	16600	5070
Pentanoic Acid	0	0	7560	1390
Phenol	7700	10200	42000	8290
Phenylacetic Acid	0	553	2410	1670
Phenylpropenoic Acid	0	9.07	602	173
Propanoic Acid, 2-Methyl-	0	1800	2230	5670
Aromatic Hydrocarbons				
Benzene	336	260	366	219
Ethylbenzene	108	314	261	624
Naphthalene	340	68.2	1040	0
Toluene	16800	4030	3730	14700
Total Xylenes	1180	1740	1260	2050
Organic Bases				
Aniline	0	10300	14000	0
Benzenesulfonamide, 4-Methyl	140	321	1200	443
Pyrrolidinone, 1-Methyl-,2-	0	6150	0	0

* 6 - Net annual precipitation of < -10 inches. Set of 2 sites.
7 - Net annual precipitation of -10 to +5 inches. Set of 3 sites.
8 - Net annual precipitation of +5 to +10 inches. Set of 5 sites.
9 - Net annual precipitation of +10 to +15 inches. Set of 3 sites.

(Continued)

Table 28. (Continued)

Compound	Mean Concentrations (ug/l) for Site Groupings*			
	6	7	8	9
Halogenated Hydrocarbons				
Chlorobenzene	0	44	1090	223
Chloroform	1300	2520	1570	2390
Dichloroethane, 1,1-	834	235	0	0
Dichloropropane, 1,2-	0	0	53.6	54.7
Methylene Chloride	8910	21100	16500	6550
Tetrachloroethylene	900	432	376	206
Trans-1,2-Dichloroethylene	0	599	71.6	0
Trichloroethane, 1,1,1-	11000	458	78.8	0
Trichloroethylene	5650	2350	1040	973
Oxygenated/Heteroatomic Hydrocarbons				
Acetone	10800	26300	32200	13300
Benzene-1,2-dicarboxylic Acid Anhydride	0	0	2380	0
Benzyl Alcohol	0	4910	25200	1360
Butanone, 2-	6290	18800	16100	9060
Cyclohexanone	825	2520	0	0
Di-n-Butylphthalate	15	390	186	227
Ethanol, 2-(2-Butoxyethoxy)-	5400	1980	0	0
Hexanol, 2-Ethyl-,1-	0	961	0	0
Hexanone, 2-	1340	6410	6230	2270
Methyl-2-Pentanone, 4--	1920	73	392	1350

* 6 - Net annual precipitation of < -10 inches. Set of 2 sites.
7 - Net annual precipitation of -10 to +5 inches. Set of 3 sites.
8 - Net annual precipitation of +5 to +10 inches. Set of 5 sites.
9 - Net annual precipitation of +10 to +15 inches. Set of 3 sites.

Table 29. ORGANICS DATA BASED ON SITE GEOGRAPHY

Compound	Mean Concentrations (ug/l) for Site Groupings*			
	10	11	12	13
Organic Acids				
Benzoic Acid	2980	11700	4910	9500
Butanoic Acid	600	19300	0	0
Butanoic Acid, 2-Methyl-	0	1360	0	0
Dichlorophenol, 2,4-	0	545	996	475
Dimethylphenol, 2,4-	1280	1460	7000	1200
Hexanoic Acid, 2-Ethyl-	0	2260	413	128
Methylphenol, 2-	7020	3720	5000	2080
Methylphenol, 4-	4200	15600	19400	5060
Pentanoic Acid	4080	6420	0	0
Phenol	39500	21500	7070	7700
Phenylacetic Acid	2170	1660	1120	0
Phenylpropanoic Acid	195	130	752	0
Propanoic Acid, 2-Methyl-	915	7470	0	0
Aromatic Hydrocarbons				
Benzene	197	289	441	336
Ethylbenzene	174	500	476	108
Naphthalene	1300	44.5	8.83	340
Toluene	9610	5270	5110	16800
Total Xylenes	333	2240	2460	1180
Organic Bases				
Aniline	17600	7750	0	0
Benzenesulfonamide, 4-Methyl	0	333	2330	140
Pyrrolidinone, 1-Methyl-,2-	0	923	4920	0

* 10 - Located in Northeast U.S. Set of 4 sites.
11 - Located in Southern U.S. Set of 4 sites.
12 - Located in Central U.S. Set of 3 sites.
13 - Located in Western U.S. Set of 2 sites.

(Continued)

Table 29. (Continued)

Compound	Mean Concentrations (ug/l) for Site Groupings*			
	10	11	12	13
Halogenated Hydrocarbons				
Chlorobenzene	1150	227	247	0
Chloroform	2640	1820	1600	1300
Dichloroethane, 1,1-	0	0	235	834
Dichloropropene, 1,2-	20.5	41	62	0
Methylene Chloride	6680	14500	26800	8910
Tetrachloroethylene	258	444	328	900
Trans-1,2-Dichloroethylene	2.75	402	178	0
Trichloroethane, 1,1,1-	0	0	589	11000
Trichloroethylene	1480	1930	503	5650
Oxygenated/Heteroatomic Hydrocarbons				
Acetone	31400	8480	40000	10800
Benzene-1,2-dicarboxylic Acid Anhydride	1040	255	2240	0
Benzyl Alcohol	14000	1920	27000	0
Butanone, 2-	17100	4900	25400	6290
Cyclohexanune	0	982	1210	825
Di-n-Butylphthalate	221	352	161	15
Ethanol, 2-(2-Butoxyethoxy)-	0	235	1670	5400
Hexanol, 2-Ethyl-,1-	0	148	765	0
Hexanone, 2-	3830	1830	11500	1340
Methyl-2-Pentanone, 4-	531	970	76	1920

* 10 - Located in Northeast U.S. Set of 4 sites.
11 - Located in Southern U.S. Set of 4 sites.
12 - Located in Central U.S. Set of 3 sites.
13 - Located in Western U.S. Set of 2 sites.

30 of the compounds. Although the sites in Group 2 accepted a wide variety of wastes, the leachate should be relatively low in organics because most of the wastes were inorganic or because most of the organic wastes were containerized and most of the inorganics were disposed as bulk wastes.

Table 28 presents a grouping of the sites based on four ranges of net precipitation (i.e., precipitation minus evapotranspiration):

- Group 6, sites with a net precipitation of less than -10 inches, includes Sites 5 and 6

- Group 7, sites with a net precipitation range of -10 to +5 inches, includes Sites 1, 4, and 10

- Group 8, sites with a net precipitation range of +5 to +10 inches, includes Sites 3, 7, 8, 11, and 12

- Group 9, sites with a net precipitation range of +10 to +15 inches, includes Sites 2, 9, and 13.

Net precipitation was selected as an indicator of site climate because precipitation and evaporation rates affect leachate generation rates and the concentration of chemicals in the leachate. Other factors which might affect the impact of net precipitation on leachate quality include: the existence and nature of intermediate or final cover at the sites, the amount and types of wastes which are containerized or disposed as bulk, and the solubilities of chemicals in the disposed wastes. The correlation of climate to leachate quality is most meaningful if sites very similar with respect to these factors are studied within different climates. However, these factors vary widely between some of the sites in this study. Therefore, any correlations between climate and compound concentrations in Table 28 probably would not be valid.

The set of sites in Group 6 of Table 28 shows fewer organics than the other groups, probably because there are fewer sites in the group. The two sites in this group actually accepted a wide variety of organic wastes. Group 9 has the next lowest representation, mostly in the chemical classification of halogenated and oxygenated hydrocarbons. Only one of the three sites (Site 9) might be expected to generate leachate low in organics based on waste input. Group 7 has the highest organic representation, yet as many as two of the three sites (Sites 1 and 4) can be expected to generate leachates low in organics based on waste input. In fact, analytical data on the full organic representation in the leachate from these sites does show relatively few organics. Therefore, many of the organics represented in Group 7 were perhaps generated by Site 10, a site which accepted a wide variety of organic wastes. Group 8 had the next highest representation of the forty organics, which is not surprising because it contains the most sites (5). Organic acids are represented least in the two groups of lowest net precipitation, while all of the organic acids are represented by the two groups of highest precipitation.

Table 29 presents site data grouped by geographic location within the continental United States:

- Group 10 consists of sites located in the Northeastern U.S. and includes Sites 7, 8, 9, and 11
- Group 11 consists of sites located in the Southern U.S. and includes Sites 1, 2, 3, and 13
- Group 12 consists of sites located in the Central U.S. and includes Sites 4, 10, and 12
- Group 13 consists of sites located in the Western U.S. and includes Sites 5 and 6.

Most of this country's hazardous waste landfills are located in the Northeastern and Southern sections of the U.S. (McCoy, 1985), so the above distribution is not surprising. Group 11 shows the greatest representation of the forty compounds, containing all except two halogenated hydrocarbons (1,1-dichloroethane and 1,1,1-trichloroethane). Three of the four sites in Group 11 can be expected to generate leachate containing a high number of organics, based on waste input. Group 11 sites are also in close proximity to the oil industry and the organic chemical companies which depend on hydrocarbons for feedstock. Many of the sites in Group 10 are not expected to generate a leachate high in organics, based on the waste input. The halogenated hydrocarbons 1,1-dichloroethane and 1,1,1-trichloroethane, plus several oxygenated/heteroatomic hydrocarbons are not represented by Group 10.

Both sites in Group 13 can be expected to generate leachate high in organics, yet there is a poor representation of organics in Table 29 for this group. However, the group contains only a few sites. All of the groups in Table 29 show a representation of the five aromatic hydrocarbons.

4.2 LEACHATE FORMULATION

Three synthetic leachate formulas (one chemically generic and two chemically specific) have been derived based on the analytical and statistical results of this study. This section presents the formulas and the justifications for the components included therein.

As noted in Section 2, liner materials are known to be affected by pH. However, pH (and Eh) of the aqueous phase of the leachate samples are not well characterized in this study. Nevertheless, based on the reported results, a pH range of 7±2 is proposed for a synthetic leachate.

Priority pollutant metals were generally in the low or fractional ppm range and were well characterized in this study. However, evidence does not suggest that these elements, occurring in the concentration ranges observed, have any impact upon liner-leachate compatibility. On this basis, priority pollutant metals are not included in the proposed synthetic leachate formulas. Commonly occurring metallic ions of such elements as sodium, potassium, calcium, and aluminum may have significant effects on clay liner permeability when present in solution concentrations of a few percent by weight. However, concentrations of these commonly occurring ions were not investigated in this study, except perhaps in a very indirect manner by means of solution-specific conductivity. There is also a lack of information regarding the importance of conductivity with respect to liner and leachate compatibility. Therefore, the proposed synthetic leachates do not include a recommended value for this parameter.

Additionally, there is a lack of information on the importance of cyanide concentrations, temperature, Eh, and COD with respect to leachate-liner compatibility, even though these parameters were determined for most of the leachate samples. Thus, a value for these parameters is not proposed.

Generally, from the standpoint of chemical effects on clay or plastic liner materials, most of the inorganic parameters analyzed in the leachate samples are largely non-reactive and may have little significance in synthetic leachate formulation. Therefore, the proposed formulations are based only on this study's organic results. However, recommendations made in Section 5.2 include continued testing for many of the inorganic parameters.

A summary of this study's leachate organic compound occurrence data is presented in Table 30. The following observations can be made:

- Organic acids, as a class, are approximately 55% (by mole fraction) phenol and substituted phenols, and 45% carboxylic acids including benzoic acid and alkanoic acids with 4 or more carbon atoms.

- The oxygenated/heteroatomic classification is approximately 46% acetone, 26% common ketone solvents, and 23% alcohols. Methanol or ethanol was not detected at any site. Ethers, esters, and aldehydes usually occurred at only one site, and in low concentrations. These three classes are not well represented by any particular compound.

- Methylene chloride accounts for approximately 61% of halogenated hydrocarbon occurrences. Dichlorinated benzenes and chlorobenzene account for about 13%, but these compounds are generally not widely distributed; none occurred at half the sites or more.

- Organic bases occurred infrequently and are absent at four sites. A single organic base did not occur at half or more of the sites.

- Toluene, benzene, and other alkyl-substituted aromatics account for approximately 92% of the aromatics group. Toluene is the most representative compound, occurring in the greatest concentration for the group and at all of the sites.

Table 30. SUMMARY OF LEACHATE ORGANIC CHEMICAL OCCURRENCE DATA

Chemical Classification	Percent Occurrence	Representative Chemical(s) and Occurrence (Mole Fraction)
Organic Acids	39.0%	Phenol (11.8%) Substituted Phenols (17 compounds at 9.5%) Benzoic Acid and Substituted Benzoic Acids (5 compounds total at 5.4%) Alkanoic acids (13 compounds at 12.3%)
Oxygenated/Heteroatomic Hydrocarbons	35.8%	Acetone (16.5%) Common Ketone Solvents, e.g., Methyl Ethyl Ketone (MEK), Methyl Isobutyl Ketone (MIBK), and Methyl Propyl Ketone (MPK)(9.2%) Alcohols of all types (16 compounds at 8.1%)
Halogenated Hydrocarbons	11.0%	Methylene Chloride (6.8%) Chlorobenzenes (4 compounds at 1.4%) Multichlorinated Alkanes/Alkenes (10 compounds at 2.8%)
Organic Bases	7.2%	Aniline and Substituted Anilines (7 compounds total at 4.3%)
Aromatic Hydrocarbons	6.0%	Toluenes (4.2%) Benzene and Alkyl-substituted Benzenes (except Toluenes) (1.4%)
Aliphatic Hydrocarbons	0.9%	This group does not have any good representatives in terms of level of occurrence or site distribution.

- Aliphatics occurred infrequently and are absent at 10 of the 13 sites. No aliphatic occurred at half or more of the sites.

On the basis of these analytical findings, certain conclusions can be drawn about the composition of a synthetic model leachate. First, the leachate should be approximately 99% aqueous by weight and 1% organic. This estimate is based on an analytical average TOC of about 0.3 grams per 100 milliliters of sample, or about 0.3% carbon. This amount of carbon would produce a weight of 1 gram (or less) of organic compounds per 100 milliliters.

As noted in Section 4.1.1, the analytical results of this study characterized only an average of about 4% of the analytical TOC present in the leachate samples. Thus, only a small portion of the 1 gram of organic material can, in the strictest sense, be defined here. However, the information generated about the characterized 4% is comprehensive. Therefore, some generalizations regarding the composition of a generic synthetic leachate, as well as specific leachate formulas, can be proposed. The organic component of the generic synthetic leachate should be composed of compounds representing several chemical groups; Table 31 presents the corresponding proportions of each group. Potential representative compounds for each group are also listed in Table 31. The organic acid group should consist of representative phenols and carboxylic acids in approximately equal proportions with respect to mole fraction. The oxygenated/heteroatomic group should consist of representative ketones and alcohols, in a ratio of about two to one, respectively. The composition of the organic portion in terms of mole fraction percentage of a specific chemical present is listed in Table 31.

Two more detailed examples of specific leachate organic fractions are shown in Table 32. These formulas carry the process of synthetic leachate formulation a step further than the general formula shown in Table 31. Results of this study were considered when assigning chemicals to the formulas. The frequency of occurrence of a given chemical (i.e., occurrence in ≥ 5 sites) was the criterion for inclusion in Synthetic Leachate A. The concentration level of a chemical was the criterion for inclusion in Synthetic Leachate B (i.e., occurrence at an average mole fraction percentage ≥ 1.0). The contribution of a chemical is shown by a mole fraction percentage. The information utilized to develop these synthetic leachate formulations was taken directly from the data presented in Tables 19 through 24.

Any attempt to formulate a synthetic leachate mixture should also take into account the approximately 96% of the organic fraction which this study did not characterize. Three approaches for this characterization are proposed.

First, the 96% unidentified portion of the organic fraction could be represented by a high molecular weight liquid n-alkane, or simply by motor oil or another refined petroleum product that forms a water suspension at the one percent level. This is proposed based on the following observations of this study:

Table 31. FORMULATION OF GENERIC SYNTHETIC LEACHATE ORGANIC FRACTION

Chemical Type	Example(s)	Mole Fraction Percent
Phenols	Phenol, Cresols	21
Carboxylic Acids	Benzoic, Hexanoic	18
Ketones	Acetone, Methyl Ethyl Ketone (MEK), Methyl Isobutyl Ketone (MIBK)	26
Alcohols	Benzyl, Hexanol	10
Halogenated	Methylene Chloride, Chlorobenzene	11
Bases	Aniline	7
Aromatics	Toluene, Benzene	6
Aliphatics	Heptadecane	1

Table 32. FORMULATIONS OF TWO SPECIFIC SYNTHETIC LEACHATE ORGANIC FRACTIONS

Compound	Compound Contribution as a Mole Fraction (m.f.) Percentage	
	Synthetic Leachate A Chemicals Occurring at ≥5 Sites	Synthetic Leachate B Chemicals Occurring at Average Concentrations ≥1.0 m.f. (x100)
ORGANIC ACIDS		
Phenol	12%	12%
4-Methylphenol	6%	6%
2-Methylphenol	3%	5%
2,4-Dimethylphenol	2%	-
2-Methylpropanoic Acid	-	1%
Benzoic Acid	6%	6%
Phenylacetic Acid	5%	-
Butanoic Acid	-	4%
Pentanoic Acid	-	3%
Hexanoic Acid	-	2%
2-Ethylhexanoic Acid	5%	-
Subtotal	39%	39%
OXYGENATED/HETEROATOMIC HYDROCARBONS		
Acetone	17%	16%
2-Butanone	5%	7%
2-Hexanone	3%	4%
4-Methyl-2-pentanone	2%	-
Di-n-butylphthalate	1%	-
Benzyl Alcohol	8%	8%
Subtotal	36%	36%
HALOGENATED HYDROCARBONS		
Methylene Chloride	5%	9%
Chlorobenzene	1%	-
1,2-Dichlorobenzene	-	2%
Chloroform	1%	-
Tetrachlorethylene	1%	-
Trichlorethylene	1%	-
1,1,1-Trichloroethane	1%	-
trans-1,2-Dichloroethylene	1%	-
Subtotal	11%	11%

(Continued)

Table 32. (Continued)

Compound	Compound Contribution as a Mole Fraction (m.f.) Percentage	
	Synthetic Leachate A Chemicals Occurring at ≥5 Sites	Synthetic Leachate B Chemicals Occurring at Average Concentrations ≥1.0 m.f. (x100)
ORGANIC BASES		
Aniline	-	3%
N,N-dimethylacetamide	-	4%
4-Methylbenzenesulfonamide	7%	-
Subtotal	7%	7%
AROMATIC HYDROCARBONS		
Toluene	3%	6%
Ethylbenzene	1%	-
Xylene(s)	1%	-
Benzene	1%	-
Subtotal	6%	6%

- The leachate samples, in general, had the appearance of homogenous suspensions or solutions, indicating that the organic mixture present was not so tarry or oily that it would not stay in suspension at the one percent level.

- Descriptions of materials disposed at the waste sites included general classifications such as "spent lubricants, oils, and greases", "industrial petroleum residues", "petroleum-based materials," and so forth. These descriptions ascribe a petroleum-like nature to the unidentified organic material.

Second, the unidentified organic fraction could be formulated based on known waste materials at a particular disposal site. This would be appropriate when testing a liner for application at a specific site.

Third, the organics already specified in the formulation could also be used to represent the unidentified fraction.

Other recommendations regarding the use of the synthetic leachate formulas will be made in Section 5.2.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This report presented discussions of site selection methodologies, physical data and sample collection methodologies, and detailed chemical analyses of leachate samples from 13 widely dispersed and varied active hazardous waste landfills. On the basis of statistical analyses of organic analytical data, a very long list of detected compounds was reduced to a short list of those compounds most representative of the major groups of components present. Utilizing this short list of chemical groups, a model or generic synthetic leachate formula and two specific formulas were derived and presented in Section 4.

The synthetic leachate formulations proposed were derived solely on the basis of the analytical data generated during this study. Any uncertainties or shortcomings in this study's data base will be directly manifested in the proposed synthetic leachate formulations.

The organic compounds quantified in this study account for, on the average, only about 4% of the carbon known to be present in the samples. Within the identified 4%, certain classes of chemicals predominate (phenols, carboxylic acids, ketones, etc.). While this information is important, it is nevertheless incomplete. Within the 96% unknown carbon, there could be organic compounds that have a large impact on liner compatibility such as halogenated, aliphatic, and aromatic hydrocarbons. Thus, this study's leachate models should be viewed only as prototypes to demonstrate the feasibility of formulating a synthetic leachate.

Attempts to compare leachates within the context of the characteristics of the respective waste sites (i.e., waste types accepted, climate, geographic region) are difficult for a number of reasons (Section 4.1.4). This study demonstrated that such leachate and waste site correlations are hindered, if not impossible, without complete and comprehensive records of the disposed wastes and knowledge of all other probable factors.

5.2 RECOMMENDATIONS

A series of recommendations are proposed which focus on expanding the significant, although in some aspects incomplete, findings generated by this study. Specifically, recommendations are geared toward: 1) use of the leachate formulas derived in this report; and 2) filling some of the data gaps regarding leachate characteristics to enable future refinement of the proposed leachate formulas.

A generic and two specific leachate formulations were proposed in this report. SAIC recommends that the best suited of these three synthetic leachate formulations be selected, following a review of the known data regarding an actual or hypothetical site and the type of waste material it does or will receive. If site-specific data are limited, a recommendation can not be made, at this point, as to which formula is best suited for liner testing.

A firm recommendation can not be made regarding how best to characterize the approximatley 96% unidentified organic fraction in the leachates analyzed during this study. However, three solutions were proposed in Section 4.2, namely:

- Represent the fraction with a high molecular weight liquid n-alkane or a refined petroleum product which will form a water suspension at the one percent level

- Formulate the fraction based on known waste materials, if a site-specific application is anticipated

- Use the organics already specified to represent the complete formulation.

The leachate samples characterized in this study are estimated to contain approximately 99% water. A mixture of 1 percent organics in water is so dilute that the action of the mixture on a plastic liner would be minimal. Also, the organic concentration in a leachate is probably quite variable with time and location within a site. Therefore, a worst case strategy is recommended for testing the effect of any proposed synthetic leachate whereby the organic portion of the leachate is at a much larger fraction than 1 percent (i.e., at least 50 percent or higher). This allows a more rapid evaluation of liner compatibility. A larger organic fraction is also a truer representation of the situation that might occur if a localized, high concentration seepage of organics came in contact with a liner (e.g., from a punctured or corroded drum).

Recommended follow-on studies are of relatively narrow scope and are designed to characterize and quantify the organic material present in a leachate as comprehensively as possible with state-of-the-art analytical techniques. Subsequent studies can branch out in many directions to better correlate leachate chemistry with site waste input, climate, site design, etc., after comprehensive characterizations of leachates are consistently performed.

With this general philosophy in mind, the next recommended step in follow-on work focuses on the enhancement of analytical results for leachate characterization and is limited to leachate from only one or two facilities. Site selection is extremely important to maximize utility of data, and the following site selection recommendations are important:

- A suitable site must have a means of representative sample collection in which premature evaporation of volatile organics is minimized.

- A suitable site must have complete historical waste handling data available for scrutiny and analysis to maximize the opportunity and ability to correlate leachate content with landfill content.

Of the 13 sites examined in this study, Sites 5 and 13 are recommended for follow-on work. These sites appear to be the most suitable candidates for the collection of representative leachate samples and appear to have relatively complete waste input data. Sites 5 and 13 have also received a wide variety of drummed and bulk wastes, both inorganic and organic, which would be represented in the leachate. A wide range of organics in the leachate provides a more comprehensive testing of any state-of-the-art analytical technology's ability to accurately detect, identify, and quantify compounds.

The balance of the recommendations deal with the analytical program. The analytical program already conducted on the hazardous waste landfill leachate samples was comprehensive. Both the data generated and the gaps, or pieces of data that could not be generated via the analytical methods employed, represent valuable information from the standpoint of planning a follow-on program. Based on what was learned from this current study's analytical scheme, the following recommendations are made with regard to a follow-on study's analytical requirements:

- Continue the program of TOC analysis of leachate samples.

- Carry out total recoverable oil and grease analyses on the samples (e.g., EPA Method 413.2), to improve the mass balance results (i.e., the agreement between analytical versus calculated TOC). This information could be very important in characterizing at least part of the unidentified organic fraction.

- In addition to carrying out oil and grease extractions, attempt other separation or clean-up procedures. Silica gel column chromatographic separation into polar, aromatic, and aliphatic fractions before GC/MS analysis will permit better separations by GC and more reliable identifications by MS. Also, a TOC or oil and grease analysis on an aliquot of each column chromatographic fraction will allow an assessment of material balance during analysis.

- Alternatively, analyze the organic components of the leachates for general chemical classes, rather than specific compounds. For instance, include total organic halogen, total phenols, and oil and grease as the key components, and correlate liner compatibility with these parameters.

- Perform a percent water determination on the sample. This procedure will give direct information about the extent of the aqueous portion of the leachate. In the present study, the percent water was roughly estimated from TOC data.

- Analyze samples on-site for pH, Eh, temperature, and conductivity as was done during this study. Although Eh and conductivity are of unknown utility in synthetic leachate formulation, these parameters can be measured along with pH and temperature with minimal effort and may prove useful.

- Either on-site or in the laboratory, determine whether the leachate sample is homogenous or whether it has a separable organic fraction that either floats or sinks. This factor determines whether or not a mainly aqueous phase or a mainly organic phase is in contact with the liner. An analytical scheme can be developed, based on this observation if necessary, for the phase that is in contact with the liner.

REFERENCES

Anderson, D. C., K. W. Brown, and J. Green. 1981. "Organic Leachate Effects on the Permeability of Clay Liners". In: Management of Uncontrolled Hazardous Waste Sites.

Anderson, D. C. and S. G. Jones. 1983. Clay Barrier - Leachate Interaction. In: National Conference on Management of Uncontrolled Hazardous Waste Sites.

E. I. DuPont de Nemours & Co. Not dated. Flexible Membranes for Pond and Reservoir Liners and Covers.

Genetelli, E. J. and J. Cirello. 1976. Gas and Leachate from Landfills: Formation, Collection and Treatment. EPA-600/9-76-004, U. S. Environmental Protection Agency. NTIS PB-251161.

Ground Water, Vol. 23. Number 4. No author. 1985. "Clay Landfill Liners: How Effective?"

Gundle Lining Systems, Inc. Not dated. Gundle Information.

Haxo, H. E., Jr., R. S. Haxo and T. F. Kellogg. 1979. Liner Materials Exposed to Municipal Solid Waste Leachate. Third Interim Report. EPA-600/2-79-038, U. S. Environmental Protection Agency. NTIS PB-299336.

Haxo, H. E., Jr., R. M. White, P. D. Haxo and M. A. Fong. 1976. Liner Materials Exposed to Municipal Solid Waste Leachate. EPA-600/2-76-255, U. S. Environmental Protection Agency. NTIS PB-259913.

Haxo, H. E., Jr., S. Dakessia, M. Fong, R. White, J. Pacey, D. Shultz and K. Brown. 1980. Lining of Waste Impoundment and Disposal Facilities. EPA-530/SW-870c, U. S. Environmental Protection Agency. NTIS PB-81-166365.

Haxo, H. E., Jr., R. S. Haxo and T. F. Kellogg. 1982. Liner Materials Exposed to Municipal Solid Waste Leachate, Third Interim Report. EPA-600/2-82-097, U. S. Environmental Protection Agency. NTIS PB-83-14780.

McCoy and Associates. March/April, 1985. The Hazardous Waste Consultant. Volume 3, Issue 2.

Schlegel Lining Technology, Inc. Not dated. Technical Bulletin, Chemical Resistance.

Stewart, W. S. 1978. State-of-the-Art Study of Land Impoundment Techniques. EPA-600/2-78-196, U. S. Environmental Protection Agency.

APPENDIX A

LISTING OF COMPOUNDS

Leachate samples from 13 hazardous waste disposal sites were analyzed for 35 volatile, 68 semi-volatile, and 13 metal priority pollutant compounds. In addition, the matching of spectra generated by the laboratory with library spectra enabled identification of 102 non-priority pollutant compounds and compound families.

The tables in this appendix list the names of the priority and non-priority pollutant compounds as follows:

Volatile Priority Pollutants	Table A-1
Semi-volatile Priority Pollutants	Table A-2
Metals	Table A-3
Non-priority Pollutants	Table A-4

TABLE A-1. VOLATILE PRIORITY POLLUTANTS

Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Butanone, 2-
Carbon Disulfide
Carbon Tetrachloride
Chlorobenzene
Chloroethane
Chloroethylvinylether, 2-
Chloroform
Chloromethane
Cis-1,3-Dichloropropene
Dibromochloromethane
Dichloroethane, 1,1-
Dichloroethane, 1,2-
Dichloroethylene, 1,1-
Dichloropropane, 1,2-
Ethylbenzene
Hexanone, 2-
Methyl-2-Pentanone, 4-
Methylene Chloride
Styrene
Tetrachloroethane, 1,1,2,2-
Tetrachloroethylene
Toluene
Total Xylenes
Trans-1,2-Dichloroethylene
Trans-1,3-Dichloropropene
Trichloroethane, 1,1,1-
Trichloroethane, 1,1,2-
Trichloroethylene
Vinyl Acetate
Vinyl Chloride

TABLE A-2. SEMI-VOLATILE PRIORITY POLLUTANTS

Acenaphthene
Acenaphthylene
Aniline
Anthracene
Benzidine
Benzo(a)Anthracene
Benzo(a)Pyrene
Benzo(b)Fluoranthene
Benzo(g,h,i)Perylene
Benzo(k)Fluoranthene
Benzoic Acid
Benzyl Alcohol
Bis(2-Chloroethoxy)Methane
Bis(2-Chloroethyl)Ether
Bis(2-Ethylhexyl)Phthalate
Bis(2-chloroisopropy)Ether
Bromophenyl-Phenylether, 4-
Butylbenzylphthalate
Chloro-3-Methylphenol, 4-
Chloroaniline, 4-
Chloronaphthalene, 2-
Chlorophenol, 2-
Chlorophenyl-phenylether, 4-
Chrysene
Di-n-Butylphthalate
Di-n-Octyl Phthalate
Dibenz(a,h)Anthracene
Dibenzofuran
Dichlorobenzene, 1,2,-
Dichlorobenzene, 1,3-
Dichlorobenzene, 1,4-
Dichlorobenzidine, 3,3-
Dichlorophenol, 2,4-
Diethylphthalate
Dimethyl Phthalate
Dimethylphenol, 2,4-
Dinitro-2-Methylphenol, 4,6-
Dinitrophenol, 2,4-
Dinitrotoluene, 2,4-
Dinitrotoluene, 2,6-
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)Pyrene
Isophorone
Methylnaphthalene, 2-
Methylphenol, 2-
Methylphenol, 4-
N-Nitroso-Di-n-Propylamine
N-Nitrosodimethylamine
N-Nitrosodiphenylamine*
Naphthalene
Nitroaniline, 2-
Nitroaniline, 3-
Nitroaniline, 4-
Nitrobenzene
Nitrophenol, 4-
Nitrophenol,2-
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Trichlorobenzene, 1,2,4-
Trichlorophenol, 2,4,5-
Trichlorophenol, 2,4,6-

* cannot be separated from diphenylamine

TABLE A-3. METALS

- Antimony
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Thallium
- Zinc

TABLE A-4. NON-PRIORITY POLLUTANTS

Acetamide, N, N-Dimethyl-
Acetic Acid, (2,4-Dichlorophenoxy)-
Alkanoic Acid
Alkanol
Aniline, 2,3-Dichloro-
Aniline, 2-Methoxy
Anthracenedione, 9,10-
Azepin-2-One, Hexahydro-, 2H-
Benzaldehyde, 4-Hydroxy-3-Methoxy-
Benzamide
Benzene, 1,2,3-Trimethyl-
Benzene, 1,2-Diamino-
Benzene, 1,3-Diamino-4-Methyl-
Benzene, 1,4-Diamino-
Benzene, 1-Ethyl-2-Methyl-
Benzene, 2-Ethyl-1,4-Dimethyl-
Benzene, Propyl-
Benzene-1,2-dicarboxylic Acid
Benzene-1,2-dicarboxylic Acid Anhydride
Benzenesulfonamide, 2-Methyl
Benzenesulfonamide, 4-Methyl
Benzoic Acid, 3,4-Dichloro-
Benzoic Acid, 4-(1,1-Dimethylethyl)-
Benzoic Acid, 4-Chloro
Bicyclo[2.2.1]Hept-2-ene, 1,7,7-Trimethyl-
Butanoic Acid
Butanoic Acid, 2-Methyl-
Cyclobutene, 2-Propenylidene-
Cyclohexan-1,2-dicarboxylic Acid Anhydride
Cyclohexanone
Cyclopentanol, 2-Methyl
Ethane, 1,1'-Oxybis[2 Methoxy-
Ethanol, 1-(2-Butoxyethoxy)-
Ethanol, 2,2'- Thiobis-
Ethanol, 2-(2-Butoxyethoxy)-
Ethanol, 2-Butoxy-
Ethanol, 2-[2-(2-Ethoxyethoxy)Ethoxy]-
Ethanol,2-(2-Ethoxyethoxy)-
Methyl Acetophenone
Heptadecane
Heptane, 2,2,4,6,6-Pentamethyl-
Hexanoic Acid
Hexanoic Acid, 2-Ethyl-
Hexanol, 2-Ethyl-,1-

(Continued)

TABLE A-4. (continued)

Isoindole-1,3(2H)-Dione, 1H-
Isoindole-1,3(2H)-Dione, 3A,4,7,7A-Tetrahydro-,cis-,1H-
Isoquinoline
Methane, Sulfonylbis-
Morpholine, 4-Ethyl-
Naphthalene Carboxylic Acid, 1-
Naphthalene, 2-Amino
Naphtho[1,8-CD]Pyran-1,3-Dione, 1H, 3H
Octanoic Acid
Pentanediol, 2,2,4-Trimethyl-, 1,3-
Pentanediol, 2-Methyl-, 2,4-
Pentanoic Acid
Pentanoic Acid, 4-Methyl-
Pentanol, 4-Methyl-, 2
Phenol, 2,4,6-Trimethyl-
Phenol, 2,5-Dichloro
Phenol, 2,5-Dimethyl-
Phenol, 2,6-bis(1,1-dimethylethyl)-4-Methyl-
Phenol, 2-Chloro-
Phenol, 3-(1,1-Dimethylethyl)-
Phenol, 4,4'-Methylenebis-
Phenol, 4-(Methylthio)-
Phenylacetic Acid
Phenylacetic Acid, 4-Methoxy-
Phenylpropanoic Acid
Phosphineoxide, Triphenyl-
Phosphoric Acid Tributylester
Propan-2-ol, 2-Phenyl-
Propanediol, 2,2-Dimethyl-,1,3-
Propanoic Acid, 2,2-Dimethyl-
Propanoic Acid, 2-Methyl-
Propanol, 1-(2-Methoxy-1-Methylethoxy)-, 2-
Pyridinamine, 2-
Pyridine
Pyridine, 2-Chloro-
Pyrrolidinone, 1-Methyl-,2-
Tetramethyl Benzene, Isomer
Tetrathiepane, 1,2,4,6-
Trimethyl Benzene, Isomer
n-Alkanes

APPENDIX B

ANALYTICAL DATA FOR ALL PARAMETERS

The results of analyses for the compounds listed in Appendix A are presented in the tables of this Appendix, as well as the results for pH, Eh, conductivity, total cyanide, COD, and TOC.

The organic compounds are listed alphabetically within a table. Each table of organics represents one of six organic classes. All of the organic data is in micrograms per liter (ug/l). The analytical results of duplicate samples from Sites 1, 4, and 7 were averaged and presented as one value. Detection limits are presented when available for a given compound and site.

The tables in this Appendix present the occurrence data as follows:

Organic Acids	Table B-1
Oxygenated/Heteroatomic Hydrocarbons	Table B-2
Halogenated Hydrocarbons	Table B-3
Organic Bases	Table B-4
Aromatic Hydrocarbons	Table B-5
Aliphatic Hydrocarbons	Table B-6
Metals, pH, Eh, Conductivity, Total Cyanide, COD, and TOC	Table B-7

Table B-1. ORGANIC ACIDS--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Acetic Acid, (2,4-Dichlorophenoxy)-	--	--	--	--	--	898	--
2 Alkanoic Acid	--	50100	1120	--	--	--	--
3 Benzene-1,2-dicarboxylic Acid	--	--	--	32.5	--	--	--
4 Benzoic Acid	15200	3090 J	20600	3220	<500	19000	<3000
5 Benzoic Acid, 3,4-Dichloro-	--	--	--	--	--	--	--
6 Benzoic Acid, 4-(1,1-Dimethylethyl)-	675	--	--	--	--	--	--
7 Benzoic Acid, 4-Chloro	--	--	--	--	--	--	--
8 Butanoic Acid	--	49400	17000	--	--	--	2400
9 Butanoic Acid, 2-Methyl-	510	2610	2340	--	--	--	--
10 Chloro-3-Methylphenol, 4-	36 J'	<1000	<1000	<100	<100	<200	<600
11 Chlorophenol, 2-	1790	<1000	<1000	<100	<100	<200	<600
12 Dichlorophenol, 2,4-	<500	2180	<1000	86.8 J'	<100	950	<600
13 Dimethylphenol, 2,4-	1390 J'	2370	1820	<100	<100	2400	30 J'
14 Dinitro-2-Methylphenol, 4,6-	<2500	<5000	<5000	<500	<500	<1000	<3000
15 Dinitrophenol, 2,4-	<2500	<5000	<5000	<500	<500	<1000	<3000
16 Hexanoic Acid	--	39700	--	--	--	--	--
17 Hexanoic Acid, 2-Ethyl-	1150	4530	1530	--	255	--	--
18 Methylphenol, 2-	2130	8330	4250	<100	350	3800	94 J'
19 Methylphenol, 4-	4080	1400	47000	260	110	10000	<600
20 Naphthalene Carboxylic Acid, 1-	--	--	--	--	--	618	--
21 Nitrophenol, 4-	<2500	<5000	<5000	<500	<500	<1000	<3000

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase

(Continued)

Table B-1. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Acetic Acid, (2,4-Dichlorophenoxy)-	--	--	--	--	--	--	--
2 Alkanoic Acid	--	--	--	--	--	--	--
3 Benzene-1,2-dicarboxylic Acid	--	--	--	--	--	--	--
4 Benzoic Acid	11900	<10000	<500	<500	<5000	11500	7990
5 Benzoic Acid, 3,4-Dichloro-	--	--	--	--	1210	--	--
6 Benzoic Acid, 4-(1,1-Dimethylethyl)-	--	--	--	--	--	--	--
7 Benzoic Acid, 4-Chloro	--	--	--	--	8220	--	--
8 Butanoic Acid	--	--	--	--	--	--	10800
9 Butanoic Acid, 2-Methyl-	--	--	--	--	--	--	--
10 Chloro-3-Methylphenol, 4-	<500	<2000	<500	<500	<1000	<1000	<530
11 Chlorophenol, 2-	<500	<2000	<500	<500	<1000	<1000	<530
12 Dichlorophenol, 2,4-	<500	<2000	<500	<500	<1000	2900	<530
13 Dimethylphenol, 2,4-	<500	<2000	<500	9000	5100	12000	242 J
14 Dinitro-2-Methylphenol, 4,6-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
15 Dinitrophenol, 2,4-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
16 Hexanoic Acid	3600	--	--	--	--	--	--
17 Hexanoic Acid, 2-Ethyl-	--	--	--	1240	--	--	1820
18 Methylphenol, 2-	<500	24000	1400	15000	4000	<1000	188 J
19 Methylphenol, 4-	1900	3900	<500	35000	11000	23000	9920
20 Naphthalene Carboxylic Acid, 1-	--	--	--	--	--	--	--
21 Nitrophenol, 4-	<2500	<10000	<2500	<2500	<5000	<5000	<2500

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase

(Continued)

Table B-1. (Continued)

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
22 Nitrophenol,2-	<500	<1000	<1000	<100	<100	<200	<600
23 Octanoic Acid	--	9440	--	--	--	--	--
24 Pentachlorophenol	<2500	<5000	<5000	<100	<100	1900	<3000
25 Pentanoic Acid	--	--	21500	--	--	--	--
26 Pentanoic Acid, 4-Methyl-	--	--	--	--	--	--	--
27 Phenol	25300	2410	42400	2400	2400	13000	3540
28 Phenol, 2,4,6-Trimethyl-	--	--	--	--	--	--	--
29 Phenol, 2,5-Dichloro	--	2760	--	--	--	--	--
30 Phenol, 2,5-Dimethyl-	318	--	--	--	--	--	--
31 Phenol, 2,6-bis(1,1-dimethylethyl)-4-Methyl-	--	--	--	--	--	--	--
32 Phenol, 2-Chloro-	1090	--	--	--	--	--	--
33 Phenol, 3-(1,1-Dimethylethyl)-	525	--	--	--	--	--	--
34 Phenol, 4,4'-Methylenebis-	--	--	--	--	--	--	--
35 Phenol, 4-(Methylthio)-	--	--	--	770	--	--	--
36 Phenylecetic Acid	1660	--	--	--	--	--	--
37 Phenylacetic Acid, 4-Methoxy-	--	--	--	--	--	--	--
38 Phenylpropanoic Acid	--	--	--	27.2	--	--	780
39 Propanoic Acid, 2,2-Dimethyl-	--	--	--	228	--	--	--
40 Propanoic Acid, 2-Methyl-	5400	--	7480	--	--	--	3660
41 Trichlorophenol, 2,4,5-	3440 J'	<5000	<5000	<500	<500	<1000	<3000
42 Trichlorophenol, 2,4,6-	3860	<1000	<1000	<100	<100	<200	<600

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase

(Continued)

Table B-1. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
22 Nitrophenol,2-	<500	<2000	<500	<500	<1000	<1000	<530
23 Octanoic Acid	--	--	--	--	--	--	--
24 Pentachlorophenol	<2500	<10000	<2500	<2500	<5000	<5000	<2500
25 Pentanoic Acid	16300	--	--	--	--	--	4180
26 Pentanoic Acid, 4-Methyl-	1180	--	--	--	--	--	2630
27 Phenol	38000	6560	<500	2800	110000	16000	15900
28 Phenol, 2,4,6-Trimethyl-	--	5720	--	--	--	--	--
29 Phenol, 2,5-Dichloro	--	--	--	--	--	--	--
30 Phenol, 2,5-Dimethyl-	--	--	--	--	--	--	--
31 Phenol, 2,6-bis(1,1-dimethylethyl)-4-Methyl-	--	26700	--	--	--	--	--
32 Phenol, 2-Chloro-	--	--	--	--	--	--	--
33 Phenol, 3-(1,1-Dimethylethyl)-	--	--	--	--	--	--	--
34 Phenol, 4,4'-Methylenebis-	--	--	--	--	5540	--	--
35 Phenol, 4-(Methylthio)-	--	--	--	--	--	--	--
36 Phenylacetic Acid	6400	--	--	--	2290	3350	5000
37 Phenylacetic Acid, 4-Methoxy-	--	--	--	710	--	--	--
38 Phenylpropanoic Acid	--	--	--	--	--	2230	520
39 Propanoic Acid, 2,2-Dimethyl-	--	--	--	--	--	--	--
40 Propanoic Acid, 2-Methyl-	--	--	--	--	--	--	17000
41 Trichlorophenol, 2,4,5-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
42 Trichlorophenol, 2,4,6-	<500	<2000	<500	<500	<1000	<1000	<530

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase

Table B-2. OXYGENATED/HETEROATOMIC HYDROCARBONS--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Acetone	16600	10100	3010	2670	18800	2750	22300
2 Alkanol	1020	--	--	--	--	--	--
3 Anthracenedione, 9,10-	--	--	--	--	--	--	--
4 Benzaldehyde, 4-Hydroxy-3-Methoxy-	--	--	--	--	--	770	--
5 Benzene-1,2-dicarboxylic Acid Anhydride	--	--	1020	--	--	--	--
6 Benzyl Alcohol	1740 J'	4090	1870	<100	<100	<200	<600
7 Bis(2-Ethylhexyl)Phthalate	1480 J'	<1000	<1000	<100	<100	<200	<600
8 Butanone, 2-	15000	<500	2110	1010	11700	884	628
9 Butylbenzylphthalate	<500	<1000	<1000	<100	<100	<200	<600
10 Carbon Disulfide	<250	<250	<25	<25	<250	<25	<250
11 Cyclohexan-1,2-dicarboxylic Acid Anhydride	--	--	--	--	--	--	--
12 Cyclohexanone	3930	--	--	--	1650	--	--
13 Cyclopentanol, 2-Methyl	17800	--	--	--	1130	--	--
14 Di-n-Butylphthalate	996 J'	<1000	413 J	22.5 J'	30 J	<200	105 J'
15 Di-n-Octyl Phthalate	31 J'	<1000	<1000	<100	<100	<200	<600
16 Diethylphthalate	<500	<1000	<1000	<100	<100	<200	<600
17 Dimethyl Phthalate	<500	<1000	<1000	<100	<100	<200	<600
18 Ethane, 1,1'-Oxybis(2 Methoxy-	540	--	16600	--	--	--	--
19 Ethanol, 1-(2-Butoxyethoxy)-	1230	--	--	--	--	--	--
20 Ethanol, 2,2'- Thiobis-	3930	--	--	--	--	--	--
21 Ethanol, 2-(2-Butoxyethoxy)-	940	--	--	--	10800	--	--
22 Ethanol, 2-Butoxy-	1560	--	--	--	--	3740	--

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase
** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-2. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Acetone	344	25500	**	59700	77500	57800	4230
2 Alkanol	--	--	--	--	--	--	--
3 Anthracenedione, 9,10-	750	--	--	--	--	--	--
4 Benzaldehyde, 4-Hydroxy-3-Methoxy-	--	--	--	--	--	--	--
5 Benzene-1,2-dicarboxylic Acid Anhydride	4180	--	--	--	--	6720	--
6 Benzyl Alcohol	56000	<2000	<500	13000	<1000	68000	<530
7 Bis(2-Ethylhexyl)Phthalate	<500	<2000	<500	<500	<1000	<1000	<530
8 Butanone, 2-	62	24700	**	40400	42900	34700	2480
9 Butylbenzylphthalate	<500	<4000	<500	<500	<1000	<1000	<530
10 Carbon Disulfide	<25	<250	**	<250	<250	<250	<25
11 Cyclohexan-1,2-dicarboxylic Acid Anhydride	--	--	--	--	--	1030	--
12 Cyclohexanone	--	--	--	3620	--	--	--
13 Cyclopentanol, 2-Methyl	--	--	--	--	--	--	--
14 Di-n-Butylphthalate	100 J	680 J	160 J	150 J	<1000	310 J	<530
15 Di-n-Octyl Phthalate	<500	<2000	<500	<500	<1000	<1000	<530
16 Diethylphthalate	<500	<2000	<500	<500	<1000	<1000	<530
17 Dimethyl Phthalate	<500	<2000	<500	<500	<1000	820 J	<530
18 Ethane, 1,1'-Oxybis[2 Methoxy-	--	--	--	--	--	--	--
19 Ethanol, 1-(2-Butoxyethoxy)-	--	--	--	--	--	8860	--
20 Ethanol, 2,2'- Thiobis-	--	--	--	--	--	--	--
21 Ethanol, 2-(2-Butoxyethoxy)-	--	--	--	5000	--	--	--
22 Ethanol, 2-Butoxy-	--	--	--	--	--	--	--

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase
** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-2. (Continued)

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
23 Ethanol, 2-[2-(2-Ethoxyethoxy)Ethoxy]-	--	--	--	--	--	--	--
24 Ethanol,2-(2-Ethoxyethoxy)-	1210	--	--	--	--	--	--
25 Hexanol, 2-Ethyl-,1-	590	--	--	434	--	--	--
26 Hexanone, 2-	1860	3740	486	964	2570	108	2860
27 Isoindole-1,3(2H)-Dione, 1H-	--	--	--	--	--	--	--
28 Isoindole-1,3(2H)-Dione, 3A,4,7,7A-Tetrahydro-,cis-,1H-	--	--	--	--	--	--	--
29 Isophorone	<500	<1000	<1000	<100	<100	<200	<600
30 Methane, Sulfonylbis-	1560	--	--	--	--	--	--
31 Methyl Acetophenone	--	--	--	--	131	--	--
32 Methyl-2-Pentanone, 4-	<500	3610	<50	11 J'	3790	48 J	1240
33 Naphtho[1,8-CD]Pyran-1,3-Dione, 1H, 3H	--	--	--	31.2	--	692	--
34 Pentanediol, 2,2,4-Trimethyl-, 1,3-	--	--	--	--	--	--	5490
35 Pentanediol, 2-Methyl-, 2,4-	--	--	--	--	--	--	--
36 Pentanol, 4-Methyl-, 2	--	33000	--	--	--	--	--
37 Phosphineoxide, Triphenyl-	--	--	--	--	--	--	--
38 Phosphoric Acid Tributylester	--	--	--	--	--	--	--
39 Propan-2-ol, 2-Phenyl-	402	226	--	--	--	--	--
40 Propanediol, 2,2-Dimethyl-,1,3-	--	--	--	588	--	--	--
41 Propanol, 1-(2-Methoxy-1-Methylethoxy)-, 2-	--	--	--	112	--	1550	--
42 Tetrathiepane, 1,2,4,6-	--	--	--	--	--	--	--
43 Vinyl Acetate	<500	<500	<50	<50	<500	<50	<500

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase
** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-2. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
23 Ethanol, 2-[2-(2-Ethoxyethoxy)Ethoxy]-	--	--	--	1560	--	--	--
24 Ethanol,2-(2-Ethoxyethoxy)-	--	--	--	--	--	--	--
25 Hexanol, 2-Ethyl-,1-	--	--	--	1860	--	--	--
26 Hexanone, 2-	17 J	1860	**	16400	10600	17200	1220
27 Isoindole-1,3(2H)-Dione, 1H-	1490	--	--	--	--	--	--
28 Isoindole-1,3(2H)-Dione, 3A,4,7,7A-Tetrahydro-,cis-,1H-	--	--	--	--	--	1630	--
29 Isophorone	<500	<2000	<500	15000	<1000	<1000	<530
30 Methane, Sulfonylbis-	--	--	--	--	--	--	--
31 Methyl Acetophenone	--	--	--	--	--	--	--
32 Methyl-2-Pentanone, 4-	17 J	173 J	**	208 J	693	9 J	271
33 Naphtho[1,8-CD]Pyran-1,3-Dione, 1H, 3H	--	--	--	--	--	--	--
34 Pentanediol, 2,2,4-Trimethyl-, 1,3-	--	--	--	810	--	--	--
35 Pentanediol, 2-Methyl-, 2,4-	--	--	--	--	2660	--	--
36 Pentanol, 4-Methyl-, 2	--	--	--	--	--	2450	--
37 Phosphineoxide, Triphenyl-	--	--	--	--	--	2390	--
38 Phosphoric Acid Tributylester	--	18200	--	--	--	--	--
39 Propan-2-ol, 2-Phenyl-	--	--	--	--	--	--	--
40 Propanediol, 2,2-Dimethyl-,1,3-	--	--	--	--	--	2440	--
41 Propanol, 1-(2-Methoxy-1-Methylethoxy)-, 2-	--	--	--	--	--	--	--
42 Tetrathiepane, 1,2,4,6-	--	--	--	--	--	--	3020
43 Vinyl Acetate	<50	<500	**	<250	<500	<500	<50

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an oil and an aqueous phase
** The 9oil phase was not analyzed for volatile priority pollutants

Table B-3. HALOGENATED HYDROCARBONS--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Bis(2-Chloroethoxy)Methane	<500	<1000	<1000	<100	<100	<200	<600
2 Bis(2-Chloroethyl)Ether	<500	<1000	<1000	<100	<100	<200	<600
3 Bis(2-chloroisopropyl)Ether	<500	<1000	<1000	<100	<100	<200	<600
4 Bromodichloromethane	<250	<250	<25	<25	<250	<25	<250
5 Bromoform	<250	<250	<25	<25	<250	<25	<250
6 Bromomethane	<500	<500	<50	<50	<500	<50	<500
7 Bromophenyl-Phenylether, 4-	<500	<1000	<1000	<100	<100	<200	<600
8 Carbon Tetrachloride	<250	<250	<25	<25	879	<25	<250
9 Chlorobenzene	132	<250	107	<25	<250	<25	2110
10 Chloroethane	<500	<500	<50	<50	<500	<50	<500
11 Chloroethylvinylether, 2-	<500	<500	<50	<50	<500	<50	<500
12 Chloroform	7250	<250	22 J	2.5 J'	2600	<25	1860
13 Chloromethane	<500	<500	<50	<50	<500	<50	<500
14 Chloronaphthalene, 2-	<500	<1000	<1000	<100	<100	<200	<600
15 Chlorophenyl-phenylether, 4-	<500	<1000	<1000	<100	<100	<200	<600
16 Cis-1,3-Dichloropropene	<250	<250	<25	<25	<250	<25	<250
17 Dibromochloromethane	<250	<250	<25	<25	<250	<25	<250
18 Dichlorobenzene, 1,2,-	173 J'	<1000	<1000	<100	<100	<200	<600
19 Dichlorobenzene, 1,3-	150 J'	<1000	<1000	<100	<100	<200	990
20 Dichlorobenzene, 1,4-	186 J'	<1000	<1000	<100	<100	<200	<600

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an aqueous and an oil phase
** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-3. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Bis(2-Chloroethoxy)Methane	<500	<2000	<500	<500	<1000	<1000	<530
2 Bis(2-Chloroethyl)Ether	<500	<2000	<500	<500	<1000	<1000	<530
3 Bis(2-chloroisopropyl)Ether	<500	<2000	<500	<500	<1000	<1000	<530
4 Bromodichloromethane	<25	<250	**	<250	<250	<250	<25
5 Bromoform	<25	<250	**	<250	<250	<250	<25
6 Bromomethane	<50	<500	**	<500	<500	<500	<50
7 Bromophenyl-Phenylether, 4-	<500	<2000	<500	<500	<1000	<1000	<530
8 Carbon Tetrachloride	<25	<250	**	<250	<250	<250	<25
9 Chlorobenzene	<25	<250	**	<250	2480	740	669
10 Chloroethane	<50	<500	**	<500	<500	<500	<50
11 Chloroethylvinylether, 2-	<50	<500	**	<500	<500	<500	<50
12 Chloroform	9 J	7180	**	317	1500	4470	<25
13 Chloromethane	<50	<500	**	<500	<500	<500	<50
14 Chloronaphthalene, 2-	<500	<2000	<500	<500	<1000	<1000	<530
15 Chlorophenyl-phenylether, 4-	<500	<2000	<500	<500	<1000	<1000	<530
16 Cis-1,3-Dichloropropene	<25	<250	**	<250	<250	<250	<25
17 Dibromochloromethane	<25	<250	**	<250	<250	<250	<25
18 Dichlorobenzene, 1,2,-	<500	46000	7800	<500	<1000	<1000	<530
19 Dichlorobenzene, 1,3-	<500	<2000	690	<500	<1000	<1000	<530
20 Dichlorobenzene, 1,4-	<500	6300	1200	<500	<1000	<1000	<530

J - estimated value
J' - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an aqueous and an oil phase
** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-3. (Continued)

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
21 Dichlorobenzidine, 3,3-	<1000	<2000	<2000	<200	<200	<400	<1200
22 Dichloroethane, 1,1-	<250	<250	<25	122	1620	47	<250
23 Dichloroethane, 1,2-	<250	<250	<25	<25	<250	<25	<250
24 Dichloroethylene, 1,1-	<250	<250	<25	<25	<250	<25	<250
25 Dichloropropane, 1,2-	<250	164 J	<25	<25	<250	<25	<250
26 Hexachlorobenzene	<500	<1000	<1000	<100	<100	<200	<600
27 Hexachlorobutadiene	<500	<1000	<1000	<100	<100	<200	<600
28 Hexachlorocyclopentadiene	<500	<1000	<1000	<100	<100	<200	<600
29 Hexachloroethane	<500	<1000	<1000	<100	<100	<200	<600
30 Methylene Chloride	39600	18300	213	2830	16500	1320	604
31 Tetrachloroethane, 1,1,2,2-	<250	<250	<25	<25	<250	<25	<250
32 Tetrachloroethylene	1160	617	<25	4.75 J'	1800	<25	<250
33 Trans-1,2-Dichloroethylene	1610	<250	<25	13.4 J'	<250	<25	<250
34 Trans-1,3-Dichloropropene	<250	<250	<25	<25	<250	<25	<250
35 Trichlorobenzene, 1,2,4-	<500	<1000	<1000	<100	<100	<200	<600
36 Trichloroethane, 1,1,1-	<250	<250	<25	313	22000	37	<250
37 Trichloroethane, 1,1,2-	<250	<250	<25	<25	231 J	<25	<250
38 Trichloroethylene	6380	1300	15 J	13.2 J'	11300	<25	77.5 J'
39 Vinyl Chloride	<500	<500	<50	<50	<500	<50	<500

J - estimated value

J' - calculated using at least one estimated value

-- - Not Detected

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

* Sample 9 separated into an aqueous and an oil phase

** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-3. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
21 Dichlorobenzidine, 3,3-	<1000	<2000	<1000	<1000	<2000	<2000	<1000
22 Dichloroethane, 1,1-	<25	<250	**	582	<250	<250	<25
23 Dichloroethane, 1,2-	<25	<250	**	<250	<250	9040	<25
24 Dichloroethylene, 1,1-	<25	<250	**	<250	<250	<250	<25
25 Dichloropropane, 1,2-	<25	<250	**	<250	82 J	186 J	<25
26 Hexachlorobenzene	<500	<2000	<500	<500	<1000	<1000	<530
27 Hexachlorobutadiene	<500	<2000	<500	<500	<1000	<1000	<530
28 Hexachlorocyclopentadiene	<500	<2000	<500	<500	<1000	<1000	<530
29 Hexachloroethane	<500	<2000	<500	<500	<1000	<1000	<530
30 Methylene Chloride	90	1330	**	20800	24700	56800	19 J
31 Tetrachloroethane, 1,1,2,2-	<25	<250	**	<250	<250	<250	<25
32 Tetrachloroethylene	<25	<250	**	131 J	1030	849	<25
33 Trans-1,2-Dichloroethylene	11 J	<250	**	175 J	<250	347	<25
34 Trans-1,3-Dichloropropene	<25	<250	**	<250	<250	<250	<25
35 Trichlorobenzene, 1,2,4-	<500	<2000	<500	<500	<1000	<1000	<530
36 Trichloroethane, 1,1,1-	<25	<250	**	1060	<250	394	<25
37 Trichloroethane, 1,1,2-	<25	<250	**	<250	<250	42 J	<25
38 Trichloroethylene	<25	1590	**	645	4270	850	30
39 Vinyl Chloride	<50	<500	**	<500	<500	<500	<50

J - estimated value
J* - calculated using at least one estimated value
-- - Not Detected
< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.
* Sample 9 separated into an aqueous and an oil phase
** The 9oil phase was not analyzed for volatile priority pollutants

Table B-4. ORGANIC BASES--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Acetamide, N, N-Dimethyl-	--	--	--	--	--	--	13800
2 Aniline	31000	<1000	<1000	<100	<100	<200	14200
3 Aniline, 2,3-Dichloro-	--	--	--	--	--	--	1150
4 Aniline, 2-Methoxy	--	--	--	--	--	--	515
5 Azepin-2-One, Hexahydro-, 2H-	--	--	7410	--	--	--	--
6 Benzamide	--	--	1500	--	--	--	--
7 Benzene, 1,2-Diamino-	--	--	--	--	--	--	835
8 Benzene, 1,3-Diamino-4-Methyl-	--	--	--	--	--	--	2480
9 Benzene, 1,4-Diamino-	--	--	--	--	--	--	1940
10 Benzenesulfonamide, 2-Methyl	--	--	--	114	--	--	--
11 Benzenesulfonamide, 4-Methyl	--	1330	--	202	--	280	--
12 Benzidine	<5000	<10000	<10000	<1000	<1000	<2000	<600
13 Chloroaniline, 4-	<500	<1000	<1000	<100	<100	<200	15500
14 Isoquinoline	--	--	--	--	--	3020	--
15 Morpholine, 4-Ethyl-	--	--	--	--	--	--	--
16 N-Nitroso-Di-n-Propylamine	<500	<1000	<1000	<100	<100	<200	<600
17 N-Nitrosodimethylamine	<500	<1000	<1000	<100	<100	<200	<600
18 N-Nitrosodiphenylamine**	<500	<1000	<1000	<100	<100	<200	<600
19 Naphthalene, 2-Amino	--	--	--	--	--	--	942
20 Nitroaniline, 2-	<2500	<5000	<5000	<500	<500	<1000	<3000
21 Nitroaniline, 3-	<2500	<5000	<5000	<500	<500	<1000	<3000
22 Nitroaniline, 4-	<2500	<5000	<5000	<500	<500	<1000	<3000
23 Pyridinamine, 2-	560	--	--	--	--	--	--
24 Pyridine	--	--	--	--	--	--	--
25 Pyridine, 2-Chloro-	3880	--	--	--	--	--	--
26 Pyrrolidinone, 1-Methyl-,2-	3690	--	--	360	--	--	--

-- - Not Detected

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

* Sample 9 separated into an oil phase and an aqueous phase

** cannot be separated from diphenylamine

(Continued)

Table B-4. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Acetamide, N, N-Dimethyl-	--	--	--	--	--	--	--
2 Aniline	<500	<2000	<500	<500	56000	<1000	<530
3 Aniline, 2,3-Dichloro-	--	--	--	--	--	--	--
4 Aniline, 2-Methoxy	--	--	--	--	--	--	--
5 Azepin-2-One, Hexahydro-, 2H-	--	--	--	--	--	--	--
6 Benzamide	--	--	--	--	--	--	--
7 Benzene, 1,2-Diamino-	--	--	--	--	--	--	--
8 Benzene, 1,3-Diamino-4-Methyl-	--	--	--	--	--	--	--
9 Benzene, 1,4-Diamino-	--	--	--	--	--	--	--
10 Benzenesulfonamide, 2-Methyl	--	--	--	--	--	--	--
11 Benzenesulfonamide, 4-Methyl	--	--	--	760	--	6020	--
12 Benzidine	<5000	<20000	<5000	<5000	<10000	<10000	<5000
13 Chloroaniline, 4-	<500	<2000	<500	<500	12000	<1000	<530
14 Isoquinoline	--	--	--	--	--	--	--
15 Morpholine, 4-Ethyl-	--	--	--	520	--	--	--
16 N-Nitroso-Di-n-Propylamine	<500	<2000	<500	<500	<1000	<1000	<530
17 N-Nitrosodimethylamine	<500	<2000	<500	<500	<1000	<1000	<530
18 N-Nitrosodiphenylamine(1)	<500	<2000	<500	<500	<1000	<1000	<530
19 Naphthalene, 2-Amino	--	--	--	--	--	--	--
20 Nitroaniline, 2-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
21 Nitroaniline, 3-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
22 Nitroaniline, 4-	<2500	<10000	<2500	<2500	<5000	<5000	<2500
23 Pyridinamine, 2-	--	--	--	--	--	--	--
24 Pyridine	--	--	--	--	11500	--	--
25 Pyridine, 2-Chloro-	--	--	--	--	6200	--	--
26 Pyrrolidinone, 1-Methyl-,2-	--	--	--	14400	--	--	--

-- - Not Detected

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

* Sample 9 separated into an oil phase and an aqueous phase

** cannot be separated from diphenylamine

Table B-5. AROMATIC HYDROCARBONS--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Acenaphthene	<500	<1000	<1000	<100	<100	<200	<600
2 Acenaphthylene	<500	<1000	<1000	<100	<100	150 J	<600
3 Anthracene	<500	<1000	<1000	<100	<100	<200	<600
4 Benzene	177 J'	324	502	8.65 J'	673	<25	270
5 Benzene, 1,2,3-Trimethyl-	2240	--	--	--	--	--	--
6 Benzene, 1-Ethyl-2-Methyl-	--	--	--	--	346	--	--
7 Benzene, 2-Ethyl-1,4-Dimethyl-	965	--	--	--	--	--	--
8 Benzene, Propyl-	--	--	--	--	176	--	--
9 Benzo(a)Anthracene	<500	<1000	<1000	<100	<100	<200	<600
10 Benzo(a)Pyrene	<500	<1000	<1000	<100	<100	<200	<600
11 Benzo(b)Fluoranthene	<500	<1000	<1000	<100	<100	<200	<600
12 Benzo(g,h,i)Perylene	<500	<1000	<1000	<100	<100	<200	<600
13 Benzo(k)Fluoranthene	<500	<1000	<1000	<100	<100	<200	<600
14 Chrysene	<500	<1000	<1000	<100	<100	<200	<600
15 Dibenz(a,h)Anthracene	<500	<1000	<1000	<100	<100	<200	<600
16 Dibenzofuran	<500	<1000	<1000	<100	<100	<200	<600
17 Dinitrotoluene, 2,4-	<500	<1000	<1000	<100	<100	<200	<600
18 Dinitrotoluene, 2,6-	<500	<1000	<1000	<100	<100	<200	<600
19 Ethylbenzene	583	1100	16 J	116	216 J	<25	<250
20 Fluoranthene	<500	<1000	<1000	<100	<100	<200	<600
21 Fluorene	<500	<1000	<1000	<100	<100	<200	<600
22 Indeno(1,2,3-cd)Pyrene	<500	<1000	<1000	<100	<100	<200	<600
23 Methylnaphthalene, 2-	<500	<1000	<1000	<100	<100	120 J	<600
24 Naphthalene	178 J'	<1000	<1000	26.5 J'	<100	680	<600
25 Nitrobenzene	<500	<1000	<1000	<100	<100	<200	<600
26 Phenanthrene	<500	<1000	<1000	<500	<500	300	<600
27 Pyrene	<500	<1000	<1000	<100	<100	<200	<600
28 Styrene	<250	<250	<25	<25	<250	<25	<250
29 Tetramethyl Benzene, Isomer	--	--	--	--	255	--	--
30 Toluene	8170	12300	32	485	33600	31	956
31 Total Xylenes	3000	4780	74	726	2360	<25	<250
32 Trimethyl Benzene, Isomer	--	--	--	300	143	--	--

J - estimated value

J' - calculated using at least one estimated value

< - The compound was analyzed for but not detected. The number is the minimum attainable detection limit for the sample.

-- - Not Detected

* Sample 9 separated into an oil and an aqueous phase

** The 9oil phase was not analyzed for volatile priority pollutants

(Continued)

Table B-5. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Acenaphthene	<500	<2000	<500	<500	<1000	<1000	<530
2 Acenaphthylene	<500	<2000	<500	<500	<1000	<1000	<530
3 Anthracene	<500	<2000	<500	<500	<1000	<1000	<530
4 Benzene	14 J	179	**	593	324	720	153
5 Benzene, 1,2,3-Trimethyl-	--	--	--	--	--	--	--
6 Benzene, 1-Ethyl-2-Methyl-	--	--	--	--	--	--	--
7 Benzene, 2-Ethyl-1,4-Dimethyl-	--	--	--	--	--	--	--
8 Benzene, Propyl-	--	--	--	--	--	--	--
9 Benzo(a)Anthracene	<500	<2000	<500	<500	<1000	<1000	<530
10 Benzo(a)Pyrene	<500	<2000	<500	<500	<1000	<1000	<530
11 Benzo(b)Fluoranthene	<500	<2000	<500	<500	<1000	<1000	<530
12 Benzo(g,h,i)Perylene	<500	<2000	<500	<500	<1000	<1000	<530
13 Benzo(k)Fluoranthene	<500	<2000	<500	<500	<1000	<1000	<530
14 Chrysene	<500	<2000	<500	<500	<1000	<1000	<530
15 Dibenz(a,h)Anthracene	<500	<2000	<500	<500	<1000	<1000	<530
16 Dibenzofuran	<500	<2000	<500	<500	<1000	<1000	<530
17 Dinitrotoluene, 2,4-	<500	<2000	<500	<500	<1000	<1000	<530
18 Dinitrotoluene, 2,6-	<500	<2000	<500	<500	<1000	<1000	<530
19 Ethylbenzene	<25	474	**	243 J	221 J	1070	299
20 Fluoranthene	<500	<2000	<500	<500	<1000	<1000	<530
21 Fluorene	<500	<2000	<500	<500	<1000	<1000	<530
22 Indeno(1,2,3-cd)Pyrene	<500	<2000	<500	<500	<1000	<1000	<530
23 Methylnaphthalene, 2-	<500	3400	680	<500	<1000	<1000	<530
24 Naphthalene	5200	<2000	<500	<500	<1000	<1000	<530
25 Nitrobenzene	<500	<2000	<500	<500	<1000	<1000	<530
26 Phenanthrene	<500	<2000	160 J	<500	<1000	<1000	<530
27 Pyrene	<500	<2000	<500	<500	<1000	<1000	<530
28 Styrene	<25	637	**	<250	<250	<250	<25
29 Tetramethyl Benzene, Isomer	--	--	--	--	--	--	--
30 Toluene	109	31200	**	3440	6170	11400	565
31 Total Xylenes	60	273	**	1510	998	5160	1100
32 Trimethyl Benzene, Isomer	--	--	--	--	--	--	--

J - estimated value

J' - calculated using at least one estimated value

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

-- - Not Detected

* Sample 9 separated into an oil and an aqueous phase

** The 9oil phase was not analyzed for volatile priority pollutants

Table B-6. ALIPHATIC HYDROCARBONS--OCCURRENCE DATA

Compound	Site 1 (ug/l)	Site 2 (ug/l)	Site 3 (ug/l)	Site 4 (ug/l)	Site 5 (ug/l)	Site 6 (ug/l)	Site 7 (ug/l)
1 Bicyclo[2.2.1]Hept-2-ene, 1,7,7-Trimethyl-	--	--	--	--	--	--	--
2 Cyclobutene, 2-Propenylidene-	--	--	--	75	--	--	--
3 Heptadecane	575	--	--	--	--	--	--
4 Heptane, 2,2,4,6,6-Pentamethyl-	--	--	--	--	--	--	--
5 n-Alkanes [A]**	--	--	--	--	--	--	--
6 n-Alkanes [B]**	2700	--	--	--	--	--	--
7 n-Alkanes [C]**	9540	--	--	--	--	--	--
8 n-Alkanes [D]**	3740	--	--	--	--	--	--

-- - Not Detected

* Sample 9 separated into an oil and an aqueous phase

** n-Alkanes are categorized on the basis of retention time as follows:

n-Alkanes [A] 10:00-14:59 minutes
n-Alkanes [B] 15:00-19:59 minutes
n-Alkanes [C] 20:00-24:59 minutes
n-Alkanes [D] 25:00-29:59 minutes

(Continued)

Table B-6. (Continued)

Compound	Site 8 (ug/l)	Site 9aq* (ug/l)	Site 9oil* (ug/l)	Site 10 (ug/l)	Site 11 (ug/l)	Site 12 (ug/l)	Site 13 (ug/l)
1 Bicyclo[2.2.1]Hept-2-ene, 1,7,7-Trimethyl-	--	17300	--	--	--	--	--
2 Cyclobutene, 2-Propenylidene-	--	--	--	--	--	--	--
3 Heptadecane	--	5440	--	--	--	--	--
4 Heptane, 2,2,4,6,6-Pentamethyl-	--	4760	--	--	--	--	--
5 n-Alkanes [A]**	--	3380	--	--	--	--	--
6 n-Alkanes [B]**	--	--	--	--	--	--	--
7 n-Alkanes [C]**	--	--	825	--	--	--	--
8 n-Alkanes [D]**	--	--	--	--	--	--	--

-- - Not Detected

* Sample 9 separated into an oil and an aqueous phase

** n-Alkanes are categorized on the basis of retention time as follows:

n-Alkanes [A] 10:00-14:59 minutes
n-Alkanes [B] 15:00-19:59 minutes
n-Alkanes [C] 20:00-24:59 minutes
n-Alkanes [D] 25:00-29:59 minutes

Table B-7. METALS, pH, Eh, CONDUCTIVITY, TOTAL CYANIDE, COD, AND TOC--OCCURRENCE DATA

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Metal*						
1 Silver	10.35	1.3	32.8	1.5	0.4	22.2
2 Arsenic	458	2096	129600	<181	<181	5741
3 Beryllium	<2.20	<0.222	0.262	0.35	<0.1	1.8
4 Cadmium	32.7	0.7	3.61	2.15	27.2	102
5 Chromium	1398	13.0	1734	52.4	43.5	5.3
6 Copper	1173	2.3	114	17.2	35.2	17030
7 Mercury	6616	449	1229	364.5	45	39300
8 Nickel	6914	178	67110	780	658	548.0
9 Lead	1006	9.0	55.8	16.35	6.9	2.6
10 Antimony	330	24.3	285	64.35	<3.4	324
11 Sellenium	3488	284	1104	890.5	812	2522
12 Thallium	62.75	9.4	18.8	16.05	11.1	156
13 Zinc	1734	49.1	1536	5.12	59.7	24510
pH	8.85	8.1-8.2	***	7.87	9.3**	***
Eh (volts)	***	***	***	-0.343	-0.241**	-0.093
Conductivity (micromhos/cm)	>20,000	7,500	8,500	>20,000	4,250	>20,000
Temperature (°C)	32	30-31	31	19.9	***	***
Total Cyanide (mg/l)	40	0.03	55	<0.02	<0.02	6.09
COD (mg/l)	10815	13600	8570	2880	1950	6490
TOC (mg/l)	2343	2004	2278	718	195	1579

* Metal data is in micrograms/liter (except for Hg, which is in nanograms per liter)

** Results are questionable due to equipment malfunction

*** Measurement not taken

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.

(Continued)

Table B-7. (Continued)

Parameter	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13
Metal*							
1 Silver	0.85	0.6	0.3	4.3	1.8	2.7	6
2 Arsenic	502	3574	<181	6056	12920	8557	758
3 Beryllium	<0.1	7.4	<0.05	0.2	0.5	<0.9	<0.2
4 Cadmium	1.1	9.8	2.9	50.5	6.3	2.6	2
5 Chromium	18.15	0.3	9.0	0.5	33.7	0.2	339
6 Copper	240	88.8	1017	279	18.1	4452	39.3
7 Mercury	<102	205	919	394	8986	606	5536
8 Nickel	484	992	17.3	3045	466	1140	1288
9 Lead	59.55	83.4	10.6	215	32.9	0.3	4.10
10 Antimony	18.7	13	<3.4	297	57.2	137	5240
11 Sellenium	730	1351	261	1103	221	1478	938
12 Thallium	10.2	<15.3	<0.2	20.2	113	46.3	16.2
13 Zinc	78.25	52.5	42.3	2526	457	1542	74.1
pH	***	***	***	7.1	***	***	***
Eh (volts)	***	***	***	***	***	***	***
Conductivity (micromhos/cm)	12,000	>20,000	***	>20,000	***	***	***
Temperature (°C)	20	***	***	***	***	***	***
Total Cyanide (mg/l)	0.01	<0.02	0.04	0.15	27.6	0.18	<0.02
COD (mg/l)	3945	13700	2070	16400	18400	23300	10700
TOC (mg/l)	1048	11750	309	4078	4909	6602	2453

* Metal data is in micrograms/liter (except for Hg, which is in nanograms per liter)

** Results are questionable due to equipment malfunction

*** Measurement not taken

< - The compound was analyzed for but not detected.
The number is the minimum attainable detection limit for the sample.